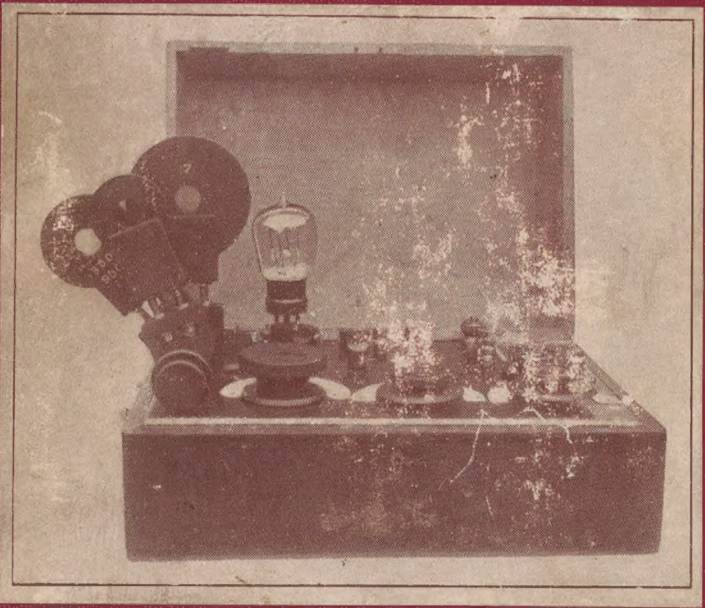
WIRELESS APPARATUS MAKING

A.V. Ballhatchet



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WIRELESS APPARATUS MAKING

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A PRACTICAL HANDBOOK ON THE DESIGN, CONSTRUCTION, AND OPERATION OF APPARATUS FOR THE RECEPTION OF WIRELESS MESSAGES

BY

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PREFACE

This little volume, it is hoped, will be of some use to those who are in the early stages of experimental work in Wireless Telegraphy and Telephony.

It does not profess to deal with the subject exhaustively, and the theoretical consideration of the subject has been eliminated as far as possible. Its aim is rather to help beginners on the constructional side of their work. Most amateur wireless workers prefer to construct as much of their apparatus as they can, or at least to assemble component parts they have to purchase because of their inability, or lack of opportunity, to construct.

The greater part of the matter is reprinted from articles which have appeared in the last few volumes of *The Model Engineer*, and the author desires to acknowledge his indebtedness to Percival Marshall, Esq., for his ready permission to use this matter. The whole has been carefully revised and such alterations and additions made as were considered necessary to bring the matter as up to date as possible. The author desires to express his thanks also to those many friends who have supplied him with the results of their own experiments and observations, and especially to Mr G. W. Hale for his help on the question of short-wave reception. Many thanks are due also to The Edison Swan Electric Co., Ltd., The Marconi-Osram Valve Co., The Mullard Radio Valve Co., Ltd., and " R. M. Radio," Ltd., for the illustrations of certain types of valves.

The subject of transmission is not touched upon, because it was considered that with the present stringent regulations concerning transmission by amateur workers, those relatively few amateurs who have been able to satisfy the authorities as to their fitness to hold such a licence will have passed well beyond the beginner stage, and will, therefore, be able to consult those larger and more authoritative works where the whole subject is dealt with in a much more exhaustive manner.

While this book was in the final stages of preparation, information became available on a question which very seriously concerns the use of valve circuits by amateurs. Considerable interference is being caused by careless and inexperienced amateurs who, while employing some circuits involving reaction, permit their valves to oscillate persistently. The large increase in the number of amateur wireless experimenters has greatly aggravated this interference. While no complete official announcement has been made at the moment of writing, it is very evident that single-circuit receivers in which a valve is employed are no longer permissible; and on no account must a reaction coil be placed directly in the aerial circuit. The simplest alternative is to couple the reactance to a secondary inductance, which is itself coupled to the aerial inductance. The coupling, however, must be so arranged that even in its tightest position the valve cannot oscillate. Amateurs must realise that there is not the slightest reason why the valve should oscillate; in fact, their reception will be much more satisfactory if it does not. Readers are advised to keep themselves thoroughly well posted in any developments which may take place.

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CHAPTER I

PRELIMINARY CONSIDERATIONS. AERIALS

As the matter presented in this volume is intended to be of some assistance to the amateur worker in wireless telegraphic experiments, it will perhaps be desirable to examine first the position of such amateurs, especially those who are in the beginning stages of this absorbing branch of electrical science.

At the present time the amateur wireless workers would seem to be composed of three main classes: (1) those who in pre-war times had obtained considerable experience in the construction and use of wireless apparatus; (2) those, mainly the younger members, who are absolutely beginners, but are very anxious to "try their hands"; and (3) those—a large number too—who during their services in His Majesty's Forces had something to do with "wireless," perhaps becoming quite efficient operators, and who now mean to keep up their one-time duty as a hobby. To the majority of these it must be obvious that conditions now are vastly different in all respects from those of pre-war times. It must be remembered that during the period of the war experiments proceeded on a very intensive scale, and an enormous amount of work was done and knowledge gained. Many formerly accepted ideas have had to be much modified, and a lot that is quite new has been added to the previous store of knowledge.

The recent wonderful development of the wireless telephone, together with the "broadcasting" of music, speech, etc., is certain to provide a tremendous incentive to the amateur reception of wireless; so that we can add to the classification of wireless workers a group which will include what may be

termed " non-technical " amateurs. These are they who will probably purchase a commercially made set and be content to listen-in with only the trouble of turning one or two knobs for adjustment. A fair proportion of those forming this group will, no doubt, eventually desire to go further than this—a most laudable intention, for, to the writer, it always seems a pity that great scientific achievements which have a direct appeal to the public fancy should produce stagnated patches of amateurs who are content to abide by the injunction, " You press the button, we do the rest."

The amateur wireless worker, then, whoever he may be, will find a very large field opened for his activities. A great deal of lost time and opportunity to make up, it may be ; but a great deal more of patient experimenting to be undertaken in the latest phases of his hobby.

The amateur wireless enthusiast of to-day has a definite and substantial position among other amateur craftsmen. That this is so is evident by the fact that quite a number of flourishing wireless societies and clubs are now in existence, and also by the establishment of several business houses who cater solely for the needs of the amateur wireless worker. Many of the older firms, too, who formerly stocked supplies for the amateur engineer, electrician, or boatbuilder, have now added to their stocks such supplies as will appeal to the several thousands of keen experimenters in this latest and most marvellous branch of electrical science.

At the outset, the writer would advise all who wish to take up this interesting study to join, if possible, a local wireless society or club. Each will obtain nothing but good by doing so. He will meet enthusiastic workers who will be ready and glad to talk over plans, failures, and successes, so that his progress will surely be greater and more certain than if he "ploughed a lonely furrow." He will, at the same time, strengthen the position of the amateur workers of the country —and therefore his own,—and secure a fuller recognition of the value such amateurs proved to the country in the early days of the war. It is quite possible, also, that a well-organised society will be able to obtain a form of licence giving much greater scope of work than an isolated worker will be granted. To the writer's way of thinking, this is as it should be.

Those in authority are alive, and rightly so, to the possibility of interference with national and commercial wireless from

careless—not necessarily wilful—amateurs; and the mere fact of a society of amateurs requiring a common licence would be sufficient guarantee of their desire to "play the game," and, if necessary, render voluntary aid in case of emergency; for such a body would be under a constant sort of surveillance, and would therefore keep within established limits for its own sake. At the same time the objectionable, thoughtless—or uncontrollable (?)—amateur would be "spotted" much more rapidly by reason of his isolation.

It is perhaps necessary to remark that no experiments in wireless work may be carried out without permission of the Postmaster-General. By the term "experiments" it would seem that the use of even what might be termed "toy" wireless sets is included; so that it would be well for the budding experimentalist not to run any risks. It will perhaps be desirable, therefore, to discuss to some extent the position of the amateur under the new legislation respecting wireless telegraphy. A preliminary notice has been issued, and is given at length below:—

Experiments in Wireless Telegraphy. Authority for the Use of Receiving Apparatus. Conditions of Issue, etc.

Formal licences to conduct experiments in wireless telegraphy cannot at present be granted; but, pending the settlement of certain outstanding questions, the Postmaster-General is prepared to authorise the use of wireless apparatus for the reception of signals on the following conditions:—

1. The applicant shall produce evidence of his British nationality and two written references. (A certificate of birth should be furnished if possible, but this will not be insisted upon if the two referees testify of their own knowledge that the applicant is of British nationality. The references should be given by persons of standing, who are British subjects and not related to the applicant);

2. There shall be no divulgence to any person (other than properly authorised officials of His Majesty's Government or a competent legal tribunal) or any use whatever made of any message received by means of the apparatus;

3. The installation shall be subject to the approval of the Postmaster-General;

4. The limits of dimensions for external aerials allowed in connection with the use of wireless receiving apparatus are as follows :—

Combined height and length not to exceed 100 feet. The height is regarded as the vertical height from the leading-in point, and the length as the length of the span. Provided the foregoing limits are observed, there is no restriction as to the number of wires that may be used in the aerial.

5. The apparatus shall be open to inspection at all reasonable times by properly authorised officers of the Post Office ;

6. A fee of 10s. shall be paid. (This charge is to cover the expenses of the issue of the licence and the inspection of the station.)

Procedure to be followed.

The applicant should furnish—

(*a*) A formal acceptance of the foregoing conditions ;

(*b*) Evidence and references as described in (1) ;

(*c*) His full Christian names and particulars of his occupation ;

(*d*) A remittance of 10s. ;

(*e*) A description of the apparatus which it is proposed to install ;

(*f*) A sketch showing the form, height, and dimensions of the proposed aerial (including leading-in wires) ;

(*g*) The address at which the apparatus would be installed.

N.B.—If the applicant is a minor, the authority to use wireless apparatus can only be issued in the name of his parent or guardian, who should comply with the requirements set forth above, and state his (or her) full address and relationship (if any) to the applicant. Evidence should also be furnished, as indicated in condition (1), of the minor's British nationality. There is no objection to a minor working the authorised apparatus as the agent of his parent or guardian.

The Postmaster-General is prepared, also, to consider applications for permission to transmit signals by wireless. The applicants must furnish evidence as to their technical ability, and that they have some definite scheme of work they are desirous of carrying out. Those desiring further particulars should apply to the Secretary, G.P.O., London, E.C.1.

One or two of the chief points most evident are, that it is simply a permit that is issued, and that transmission to the

majority of amateurs, the beginners at any rate, is absolutely barred. To most who were able to form any opinion on the matter, it must have been anticipated that transmission would be the most knotty problem to solve, and this would have its reflex in the use of thermionic valves; for it must be remembered that in certain methods of reception when using valves, the aerial is charged with energy from the valve itself, and that this energy, although not of very high order, is sufficiently strong to form an obstruction to other receiving instruments within a fairly wide area. Already, even, complaints have been made as to interference of this very nature, and the more influential of the wireless societies are taking up the matter, being seriously disturbed, and rightly so, for they fear that should such interference continue, or increase, drastic measures may be taken by the State. It would not at all surprise the writer to find that permission to transmit will be very difficult to obtain for some time yet, and that such permits will be pretty well confined to members of reputable wireless clubs or societies; and, at the risk of raising a storm, he ventures to give the opinion that this will be the best solution of what is admittedly a difficult matter for the P.M.G. to decide. The amateur will always have the writer's entire sympathy—brotherly sympathy, in fact,—but he is perfectly sure that he will always have the support of all conscientious amateurs in strongly condemning the one-time amateur wireless man who, without any thought or consideration, discharged into the long-suffering ether oscillations of all "shapes and sizes" just whenever he fancied. One does not like to think that there are many who would deliberately do so, but that they act in such a manner through ignorance—the ignorance begotten of a little knowledge. The best cure for such is, obviously, for them to acquire more knowledge; and where could they get it better than from the members of a society who are themselves only too anxious to make things easier for the whole fraternity of amateur workers? Finally, if these notes should reach the eyes of any who scorn advice of such a nature, the writer asks them to pause, and consider the big strides that have been made in direction-finding, and also the fact that they will have all the self-respecting and law-abiding amateurs against them.

While on the question of the issue of permits, it may be of interest to some readers to know that, if desired, the permit

may be in respect of a portable receiving set. This would apply, for instance, to a club; or a Scout troop, when it is desired to fit up a temporary receiving station for just a few hours' practice. The permit would be issued to some responsible person who would be in charge, and the fee of 10s. would be payable just as though the station was situate at some permanent address.

The size of the aerial allowed by the above permission will quite possibly come as a shock to many, for such an aerial is undoubtedly on the small side. But, at the same time, two things must be kept in mind. First, the size of aerial allowed is only in respect of the present provisional permit and will no doubt be modified considerably when the regular licences are available; second, that with well-designed and carefully constructed apparatus very good work can be done with such an aerial, especially if one or more valves be used for amplifying. Finally, it should not be inferred from a perusal of the conditions under which a licence may be issued, that the matter bristles with difficulties. Far from it; there is every desire, now, to encourage the amateur, and it is quite possible that considerable modifications in those conditions will be made in the near future.

Aerials.—It is taken for granted that every reader will understand that, in order to receive wireless signals, there must be provided some means of intercepting the wave trains of energy travelling through the ether. The exact phraseology of the above statement may be open to objection by some, but it will suffice for the moment. The means most generally adopted is to suspend as freely as possible in the air one or more strands of wire or metal tape. This conductor, most carefully insulated electrically, is attached to the detecting apparatus, which is also electrically connected to the earth. What really happens in this case is, that the metal wire, or aerial, and the earth or those objects in electrical continuity with it, between them form the two surfaces of a condenser, and the detecting apparatus joined between these two surfaces taps off energy from them and renders that energy evident. A little thought will make it clear that it should not be necessary to have what is generally understood as an aerial, but that any arrangement which will provide this condenser condition should serve. This is quite true; and provided the condenser

effect is great enough and the apparatus used in conjunction with it is sensitive enough, then it is quite possible to receive signals letting just a few feet of wire, or even the body of the operator, serve in place of an exterior aerial. A little will be said in connection with this matter later, however, and for the present we will confine our attention to the regulation outdoor aerial.

This is a subject where previous knowledge has been considerably modified. With the use of valve amplifiers, etc., aerials of types formerly considered impossible, or at least woefully inefficient, can be used quite successfully. Conditions in active war service have made this very apparent. The long, high, many-stranded aerial formed an excellent target, for instance, and so it was quite common, eventually, to find "aerials" erected being nowhere in their length more than a few inches above the ground, or even buried. It must not be supposed that the use of such aerials is advocated to the exclusion of others of more customary forms. Far from it. These low aerials gave good service, but at the same time they had strict limitations.

The amateur is advised to construct an aerial as high and as long as circumstances—and his licence—will allow. The subject is difficult to discuss with much satisfaction, as conditions vary so largely. Some will have no difficulty in rigging up an aerial of good design and ample proportions, while others will have to exercise considerable thought to get the best under their particular conditions; while others, again, will no doubt have to be content with aerials that would be considered more or less makeshift.

Aerials may consist of one or many strands of wire, and, as the reader is no doubt aware, they may take many forms: the T, the inverted L, the "umbrella," the "squirrel-cage," and so on. Then, again, they may be made directive to a considerable extent. The writer is not desirous, by any means, of entering into theoretical or controversial arguments on this question, but believes that an inverted L-shaped aerial of two strands, and of sufficient length, will prove most generally useful. For those who wish to save a little in expense, or who are obliged to consider the question from a constructional point of view, the same form, but of one strand only, will serve. After all, the choice of aerial will, for the amateur, resolve itself fairly simply. He is permitted to use 100 ft.

Now, if the aerial is high and his operating room low, the lead-in will absorb a good proportion of that length. Then, if he has space enough to utilise the remainder, he will be well advised to use a single-wire aerial. On the other hand, if the lead-in is short and the available space cramped, then a twin-wire aerial is certainly the solution. Between these two extremes there will, obviously, be many means, and in these cases the amateur must use his own discretion. The question of suitable wire opens another vexed point. Wire of all kinds is now much more expensive than formerly, so that an aerial of braided or stranded bronze wire will be a big item in prime costs. The writer has found a tinned copper wire of about No. 18 or 20 S.W.G. give very fine results. Some argue against the tin covering, but the objection is hardly likely to be appreciated by the amateur, while for use in towns where the atmosphere is considerably tainted the tin is of value. The outstanding disadvantage of a wire of this description is, perhaps, its stiffness. If the aerial is to be, practically, a permanent affair, this objection is not apparent; but as a great many amateurs like to be able to raise and lower their aerials occasionally, then a stranded wire will prove much more convenient to handle. The "lead-in" can be of the same wire as the aerial proper, or it may take the form of a many-stranded wire, rubber-covered for preference. Any joints should be soldered, and all traces of flux must be carefully removed. Some authorities recommend the covering of wires by enamel or other weather-resisting material; indeed, enamel-stranded wire could at one time be purchased. The covering will make no difference in actual working, and will certainly add to the life of the wire. And here the writer would make mention of a most excellent material for such purposes. It is a bitumastic paint prepared by Griffiths Bros., of Bermondsey. It is quite inexpensive, dries quickly, and is impervious to weather and acid fumes. It appears to give quite a non-hygroscopic surface to wood or metal, and moisture falling on it resolves itself into drops instead of forming a film, which would, of course, be conducting.

Some form of insulator is essential for suspending the aerial from the poles or other supports. Porcelain or china is the best material, provided it is "electrical" porcelain. Many firms, such as Doulton, of Lambeth, and Gaskell and Grocott, of Longport, specialise in such insulators. They are not

expensive, and are exceedingly reliable, the only possible objection to their use being, perhaps, their weight. But this is, after all, very small in the sizes such as the average amateur would use. Ebonite does not seem to be all that might be supposed. In the first place, it is brittle, and so requires to be of considerable bulk in order to provide the requisite strength. This naturally causes expense to mount up, as it is by no means a cheap material. Then, some varieties appear to weather very badly.

However, very useful insulators may be made from small

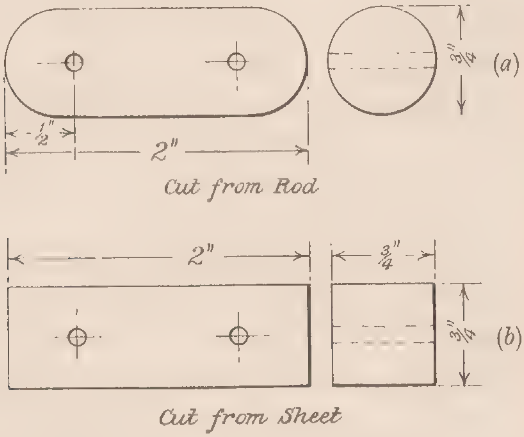


FIG. 1.—Simple Ebonite Insulators.

pieces of ebonite, either rod or thick sheet. Fig. 1 gives dimensions of ebonite insulators sufficiently large for the amateur's aerial, (*a*) being made from rod, and (*b*) from a piece of stout sheet. It is as well to make the holes no larger than are required to allow the wire or cord to pass through comfortably; and the edges of the holes should be countersunk a little in order to remove the sharpness, as ebonite is hard enough to cut into copper.

It may come as a surprise to many to be told that wood, properly prepared, makes quite an efficient insulator. A hard, close-textured wood should be chosen, and dressed with several coats of a preparation such as that mentioned above. A sketch is appended of a wooden insulator largely

used in the Signal Service (fig. 2). It is of hornbeam and approximately to the dimensions given. It is in two parts, an outer, which is bored internally and screwed at the upper end of the bore to take the screwed end of the central wooden rod. The lower end of the rod is provided with a hole which carries an end of the aerial, while the upper end of the outer portion is drilled through and fitted with a string or wire loop, this forming the suspension. The whole is given a coat of paint, and is, of course, used with the loop uppermost. The insulator is very light and strong, and far more efficient, electrically, than one would imagine. Incidentally, it would form a capital exercise for the amateur who fancies himself at lathe-work.

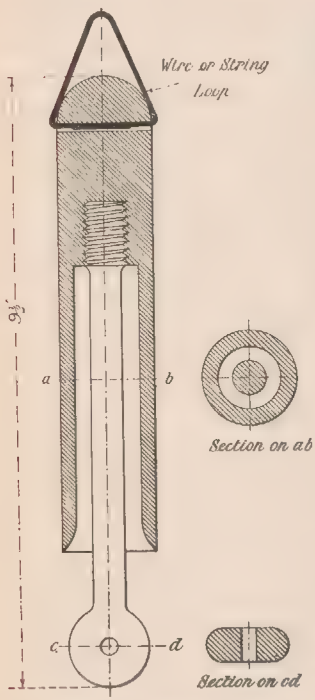


Fig. 2.—Wooden Aerial Insulator.

With an aerial of more than one strand it becomes necessary to use "spreaders" to keep the wires apart. These should be as stiff as possible and yet of material that will add as little weight as possible. If the spreaders are to be short—as they most probably will be, though less than 4 ft. is not advisable—wood or bamboo will serve very well, but they must be well dressed with some preservative. Strong wire loops, or "eyes," should be firmly fixed at the ends, and a strong lashing of tarred cord put on to guard against splitting; for it must be remembered that a great strain is put upon all parts of an aerial owing to swaying due to air currents. The cumulative effect of continual swaying is far greater than many would suppose. The actual suspension could be of galvanised steel or *stout* bronze or copper. Failing this, a stout *woven* cord, well served with some preservative such as Stockholm tar, will give very good service. The aerial

wires themselves should be fastened to insulators, which in their turn are made fast to the eyes at the ends of the spreaders. The halyards, if any are used, should also be of good woven cord, and it is not at all a bad plan to knot the ends together after the cord has been run through the pulley. This avoids the annoyance of having to let down the pole, or perform sundry and risky acrobatic performances because the cord has escaped and run completely through the pulley. This may sound like "grandmotherly" advice, but such a thing has happened on more than one occasion—and will happen again!

The aerial will need some support, of course. And here again the amateur must decide for himself and be guided mainly by existing circumstances. Chimney stacks or trees are excellent, provided due precautions are taken. Chimney stacks are best utilised in the same manner as is adopted by the Post Office engineers. That is, to encircle the stack with a strong wire, preferably stranded, and place angle pieces at the corners to prevent chafing of the wire, or any cutting into the bricks by the wire. A tree is best utilised by fastening to the trunk, or a *stout* branch, a piece of stranded wire of such length that the actual aerial is brought well away from the smaller branches or leaves. Beware of a branch that is likely to sway much. Trouble is sure to follow otherwise. The question of poles is largely one of expense. If it is thought advisable to use a pole either complete in itself (that is, to form a mast), or as an extension to a chimney stack or tree, then the main factor is the weight of the aerial—allowing a good margin for wind pressure—other factors being the stiffness or otherwise of the pole, the method of fastening it, and the provision of suitable guys. From the writer's point of view, the money expended on a *good* pole is well invested. How very unsatisfactory, for instance, some of the pre-war poles appeared, with their forlorn-looking droops, and what vexation of spirit must have been endured by some who erred on the side of lightness. On the other hand, it must not be overlooked that a heavy pole requires some careful handling when being erected. A pole over 30 ft. in height is most satisfactorily raised by means of a falling derrick; while one over 50 ft. is much better if made in sections, and these made to hoist on the same principle as a ship's mast. Guys play a very important part in the stability of a mast or pole, and

should never be omitted even with the shortest pole. They should be, preferably, of galvanised steel cable, and if of fair length, should be broken somewhere by a porcelain insulator. Masts from 30 ft. to 50 ft. require at least eight guys, and if over 50 ft. from twelve upwards. For masts up to 30 ft. ordinary gas barrel is satisfactory. The barrel may be of graduated sizes, the different sizes being fitted together with reducing sockets. The upper section should not be less than $\frac{1}{2}$-in. barrel, while the middle and lower should be of $\frac{3}{4}$ in. and 1 in. respectively. It might be mentioned here that gas barrel is measured internally, so that the external diameter is considerably more than the mere name would at first suggest. Such a mast should most certainly be stayed or guyed, and for a 30-ft. mast made in three sections, the stays might well be taken from the reducing sockets and also from the upper end. Whenever wire is used as stays, each stay should be broken somewhere in its length by an insulator. This is not to prevent actual leakage, but to prevent each stay acting as a small capacity in itself and so, most possibly, setting up some little interference with the aerial.

The writer feels quite sensible that these remarks are far from complete, or that the whole ground has been covered, but it must be very apparent that the problem of aerial supports is entirely one for the individual, and the chief objects of the points raised are to lead the amateur (especially the beginner) to consider well over the question and so save possible disappointment, worry, or perhaps needless expense.

It is not necessary, perhaps, to say much about the lead-in. It must be kept away as far as possible from walls or suchlike, metal roofs or gutters being the most troublesome, and very carefully insulated where it actually enters the building. For this purpose tubes of china-ware can be purchased, and those with a bell mouth are the best. The bell mouth should point to the ground, and the wire led with a good ample loop upwards into it. An ebonite tube serves well if it is given an occasional clean-up with magnesia and water. This removes the oxidised products on its surface.

The question of a suitable "earth" is most important. To those living in towns nothing could be better than a water-pipe, and a pipe leading direct to the ground is better than one which comes away from the cistern. Let the earth-wire, which comes away from the work-bench or table, be as short

as possible and of good substance, partly to avoid any unnecessary resistance, but mainly to form a good path for atmospheric discharges. For it must be remembered that an aerial is a good lightning conductor, using the word conductor literally. Also keep the earth-wire well away from the aerial lead-in. Condenser effects between the two are easily set up, and are very troublesome. Never mind the neat appearance of two wires coming down to the work-bench in china cleats and exactly parallel all the way. Make the connection to the water-pipe of ample surface. Scrape the pipe quite clean, and make a stout brass clip which can be screwed on tightly. Those who are not able to use a water-pipe—in country districts, for instance—must fall back on the buried-plate system, so often described. If a spot that is always more or less damp can be selected, so much the better. Whatever else may be used, do not on any account use a gas-pipe.

As regards the material for the actual earth, the best is undoubtedly fairly coarse copper gauze, a piece about 6 ft. or 8 ft. long by 2 ft. wide serving admirably. This will probably be familiar to some readers as the "earth mat" so largely used by the Signal Service. The one objection to such an earth is its expense, and a very good substitute takes the form of one or two sheets of galvanised iron. A few yards of wide galvanised wire-netting is also quite suitable, though its life is not very long. Whatever is used should be buried a foot or so below the surface, and lying parallel to the surface, not edgewise. The very best place for such an earth is right below the aerial if possible, and with its length in the same direction as the length of the aerial. If the remarks on the condenser effects existing between the aerial and earth be recalled, the reason for this is obvious. A good substantial lead of copper wire should be soldered to the earth plate or net, and it is not at all a bad plan to take leads from several places around the edges, soldering them all to a common lead which will enter the house. In this case, should one fracture or become badly conducting through corrosion, the earth is still capable of carrying out its function.

Lastly, and most important of all, arrange a substantial switch to join aerial and earth direct when the set is out of action. It need not be elaborate, but should provide plenty of metallic surface and make really good contact. It may be possibly save the set from disaster, to say the least.

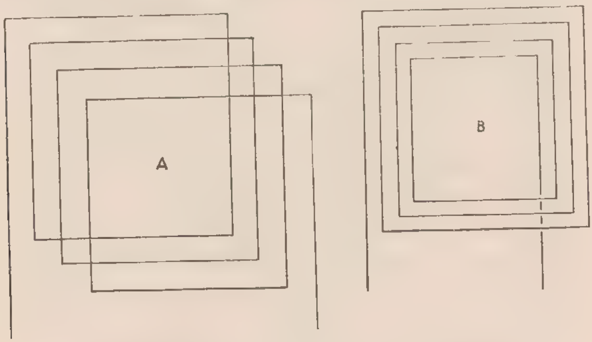
Frame or Loop Aerials.—This chapter would hardly be complete without some reference to the subject of frame or loop aerials. Many amateurs have seen or heard of reception being carried out in a room when no exterior aerial was employed. This method would, as first sight, appear to be the ideal from the amateur's point of view; but many who have experimented in this direction have been greatly disappointed. It must be remembered that an aerial of this type is a very inefficient absorber of electro-magnetic energy, and that some form of amplification is necessary in order to render the small amount of energy absorbed of any practical use.

The frame aerial is almost essentially a development of experience gained during the war. The use of anything like the conventional aerial in the zones of actual fighting was, except on rare occasions, almost impossible. When it is remembered that the combatants lived what was practically an underground life, the fact becomes obvious. Thus, then, was the inception of the loop aerial, and experiment and development proceeded apace. It gained enhanced value when the fact was recognised that this particular form of aerial gave most pronounced directional effects.

The frame aerial or loop forms with the aerial inductance of the receiving apparatus a closed circuit, and replaces the condenser condition provided by the usual aerial and earth system. Those amateurs who will be able to use two or three valves for amplification will find the use of a frame aerial a source of great interest. It is cheaply and easily constructed, very portable, and the problems connected with its use are not yet by any means solved, neither are its full possibilities yet realised. So that from an experimental point of view alone the frame aerial is well worth consideration.

It will be plain that there are two ways in which the wire composing the loop may be wound. The turns may lie in a horizontal or vertical plane (fig. 3). The former is generally termed the solenoid type, while the latter, for want of a better term, has been called the pancake form. The latter is probably the better, as construction is simpler and there would seem to be some little advantage in actual use. The turns of wire should take a rectangular form (though this does not by any means imply simply square), and means must be provided so that the whole aerial—the wire and its support—may be rotated

on a vertical axis; while, if matters can be so arranged, it is also a great advantage to be able to swing the frame on a horizontal axis. The actual frame support can be made of wood, and should be substantially made, so that the true rectangular form may be maintained. It will be found that the turns of wire will impose a considerable strain on the supports, so that provision must be made to avoid distortion as far as possible. The aerial illustrated in fig. 4 is supported on a frame of sound wood, free from knots, and 1 in. square and well varnished. The vertical member is longer than the horizontal, and its lower end is rounded and fits into a socket attached to the



Solenoid. Pancake.

FIG. 3.—Methods of winding Loops.

foot. As to fastening the wire to the supports, various methods may be adopted. In large loops it is customary to fix pegs at the correct distance apart, and wind the wire over these. The writer adopted a rather simpler method. The faces of the wooden arms receiving the wire were chamfered as shown in fig. 5, and then fine slots were made across the edges so formed. This seems to answer quite well, though there might be some possibility of breakage if great tension was put on the wire.

Now as to the size of the frame, the number of turns and gauge of the wire, and the spacing of the turns, it is only possible to speak in general terms. It may be stated at once that each individual frame has its own characteristics, and that all the considerations mentioned above are the main factors determining these characteristics. It is as true of

frame aerials as of receivers in general, that it is hardly possible for one piece of apparatus to give equal efficiency over the whole range of wave-lengths now in use. It may be taken

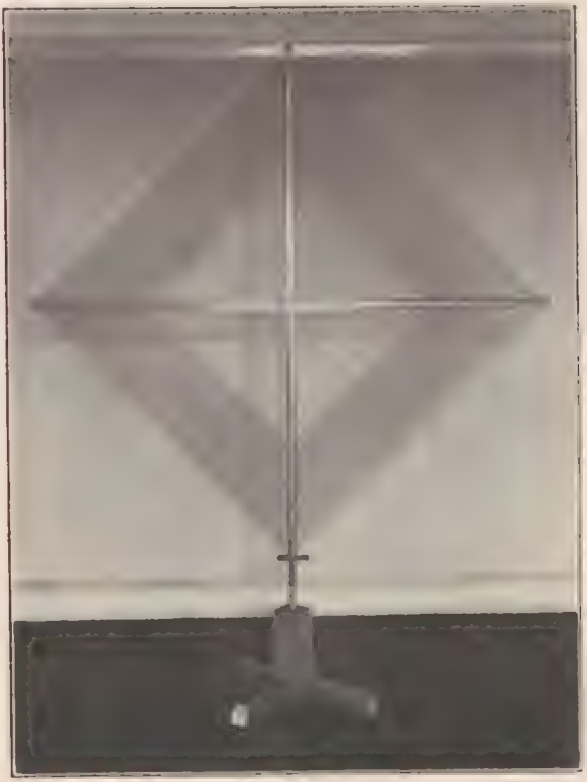


FIG. 4.—Photograph of Frame Aerial.

as a standard that a large frame aerial with few turns of wire is best for short wave-lengths, while a smaller one with a greater number of turns is better for long waves. As some guidance, the one illustrated will be described in detail. The outer turn of wire forms a square of 4 ft. side, it has fifty turns of No. 22 S.W.G. copper wire spaced $\frac{1}{4}$ in. apart, and its

natural wave-length is about 2200. A frame aerial larger than 5 ft. across becomes cumbersome, while one about 1 ft. across would be about the smallest to be of much service. The wire should not be too fine, and either No. 20, 22, or 24 gauge is most suitable. The wire, being spaced, makes the question of insulation of little moment; bare wire might be used, though it is better covered, and one of the cheapest and simplest wires to use is the ordinary 22-gauge bell-wire. For an aerial of the size under notice, the spacing should not exceed $\frac{1}{4}$ in., or the inductance value of the aerial will fall off considerably; while if it is less, damping due to impedance will rise. The outer and inner ends of the wire will be brought to the "aerial" and "earth" terminals of the tuner, and it will most probably be necessary when receiving signals on long wave-lengths to put a loading coil in series with the aerial and aerial inductance of the tuner. It will also be found an advantage, as a general rule, to use an aerial inductance of small diameter rather than a large one. The condenser in the aerial circuit should be used as sparingly as possible, and under no considerations should exceed 0·001 mfd. capacity; and it is certainly best to keep the aerial as high as possible. When searching for signals, the aerial should be slowly rotated while tuner adjustments are made until the strongest effects are obtained. Reference to a larger work, where the question of direction-finding is discussed, will provide the amateur with material for much interesting experiment.

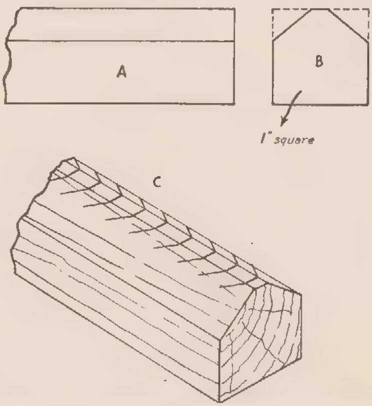


Fig. 5.—Shape of Supporting Arms of Frame Aerial.

CHAPTER II

INDUCTANCES

It is proposed to devote some little space to a discussion of the actual instruments used in a W.T. station (that is, from the average amateur's point of view), not so much in the way of the general lay-out, but more particularly concerning the constructional details.

The writer does not desire to offer a complete specification for a receiving set; that has often been done before, and a perusal of the back numbers of the *Model Engineer* will bring several such to light. The majority of these are descriptions, more or less detailed, of sets actually constructed by amateurs, and it is greatly to be hoped that we shall soon have similar descriptions recurring in those pages. But the present writer's purpose is rather to discuss in a broader manner the components of a set, offering suggestions as to construction, and alternative methods of forming a complete set. It would not be so easy as some would suppose to offer a complete specification for a receiving set that would, in the first place, give universal satisfaction in working, to say nothing of satisfying the ideals of all those who contemplate building a set. Conditions vary so largely, so many factors enter into a design, and the capabilities of individuals vary so much from a constructional as well as a manipulative point of view, that it would be a very unlikely happening for a specification to meet with general approval. And the writer ventures to think that more good will accrue to the amateur if he works out his own design from general principles than if he copies, more or less blindly, from what is almost bound to be a somewhat stereotyped set of apparatus. Our American cousins are rather gone on the idea of "standard" wireless sets for amateurs. The idea has certain good features, and was brought into being, most probably, by the very stringent laws at one time concerning such workers. But, as has so often been urged, the amateur should strive after originality; and, after all, to the writer's way of thinking, there is far more charm and ultimate satisfaction in knowing that one's production contains some parts, at least, that are the outcome of one's own thoughts. Prompted and directed those thoughts may be, perhaps, but then how much know-

ledge is really gained intuitively, especially in the realms of science?

So, having thought a little on aerials, our next consideration shall be that of inductances.

In its simplest stage a receiver consists of an oscillatory circuit containing some means of rendering the energy in it appreciable to the senses; and an oscillatory circuit must possess inductance and capacity. In order to make most use of the effects of inductance for receiving purposes, the bulk of the wire used in the circuit takes the form of coils of various shapes and sizes. Now the oscillating current, always very small, is largely reduced or "damped" by resistance, and resistance is chiefly determined by the size (cross-sectional area) and length of the wire used. Resistance must, therefore, always be present, but it must be as little as possible; hence the use of a thick wire is indicated. But an inductance is usually of very many turns, and as space and weight are a consideration, and a thick wire is rather more awkward to handle than one thinner, the size of wire generally used is either No. 24, 26, or 28 S.W.G. The covering is of no great moment, except that it should not be too thick. Single cotton serves quite well if the wire is varnished. Single silk is a little more expensive, but winds a little closer. Enamelled wire is good, but requires a fair amount of care in handling.

There are three common ways of winding an inductance:—(1) the ordinary single layer of wire wound on a suitable support; (2) the "lap-winding," where two or more layers are put upon a mandrel; and (3) the "basket" or "pancake" method, where the wire is wound on a special shaped former. The support for the first two is generally in the form of a tube which is of length and diameter to suit the particular design of which the coil will form a component, and may be of various materials. Cardboard tubes if of fair substance and well varnished are quite satisfactory, while for the fastidious worker tubes of ebonite or other compounds of somewhat similar nature are available; or he may obtain the excellent, but expensive, "Paxolin." The mandrels need not be circular in form, but those of rectangular outline require to be much thicker in substance in order to obtain the requisite strength.

Little can be said with regard to the ordinary single winding, except that it should be as close and even as possible, special care being taken to make the ends secure. Avoid kinks, and

finish by giving the whole coil two coats of fairly thin shellac varnish. Thin varnish penetrates better than thick, and dries more quickly. Less dust is therefore liable to be included in the coating, and a more pleasing surface results. Dust is a most insidious enemy in wireless sets. Lap-winding is hardly likely to be practised much by the amateur. Its chief advantage seems to lie in the fact that a great deal of wire can be got into a small space, *i.e.* an inductance so wound takes more the form of a ring than a cylinder. The writer knows of one splendid set, if it is still in being, where all the larger inductances were so wound ; in fact, he helped in its construction. Now the difficulty lies (and it is not at all an easy matter to do such winding nicely) in the fact that the wire may not proceed forward to the end of the mandrel and then back again over the first layer, and so on, as is the usual method of winding a bobbin. Results, when using oscillatory currents, would be very poor. Instead, the winding must proceed up and down ; and when winding by hand, the " down " is practically impossible, all the layers being in the " up " direction. So that a section of lap-winding appears somewhat as shown in fig. 6, where the wire is shown very much exaggerated. The great trouble is the annoying way in which some layers of wire will spread out and so let an upper turn sink down between them. The ordinary wire seems to possess an extraordinary amount of springiness and to be most intractable, while a softer wire (a stranded one, for instance) is just as difficult to keep in place and shape. The covering on the wire seems to develop an unusual slipperiness, and the whole secret seems to lie in the amount of tension kept up while winding is in progress. The writer found a great help in using finely powdered resin on the fingers, but must confess that lap-winding is a very tedious and trying job. Three methods for commencing are shown. In (*A*) six layers of wire are put on first, in the order shown, and these give the correct angle by which the succeeding layers are supported. In (*B*) the support is formed by putting in six layers of a hard string of the same diameter as the wire. By far the best method is shown at (*C*), where the support is formed of the same substance as the mandrel, though this is, of course, only possible when the mandrel is turned up from ebonite, wood, or other suitable material. The ridge at an angle of 120 deg. with the surface forms an excellent support as well as a protection to

the wire. In the diagrams the wire is shown as being three layers deep, but this depth is by no means binding, though it will be found that with greater depth trouble comes on apace.

The "basket" winding is an extremely neat and simple way of producing what is in reality a form of lap-winding. Inductances made in this manner contain a huge amount of wire in a very small space. Some authorities dislike the

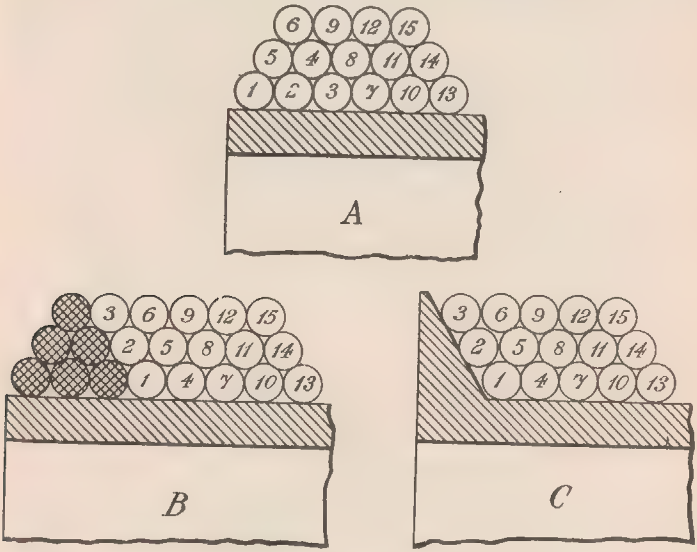


FIG. 6.—An exaggerated sectional view of Lap-winding.

method on account of what is known as condenser effect in the inductance itself. That such effects do exist there is no doubt, and no opinion for or against is offered here. The writer has seen and used inductances of this type which gave very good service, and the condenser effects can be greatly diminished if a disc of empire cloth, thin presspahn, or even stout well-waxed paper be placed between the separate units. The sketches in fig. 7 show two methods of procedure, and the finished units are shown in the photographs. In (*A*) a wooden disc of suitable size is prepared, and its periphery marked out into an *odd* number of equal spaces (7, 9, or 11 being most

general). Small holes are drilled radially and fitted with thin pegs of wood, ebonite, or metal. Winding then proceeds from the edge of the disc, the wire being taken *over* one peg and *under* the next, and so on until the desired limit of size is reached. Each successive circle (?) of wire should be kept well down on the previous one, and the end given a turn or two round the nearest peg. The whole should then be dipped in melted wax, removed after a minute or two, and then allowed to set. The pegs can then be withdrawn, and a compact, flat cake of wire results. In (*B*) a disc of presspahn or similar insulating material is slotted radially as shown, the number of slots being an *odd* one as before. Winding is done in a

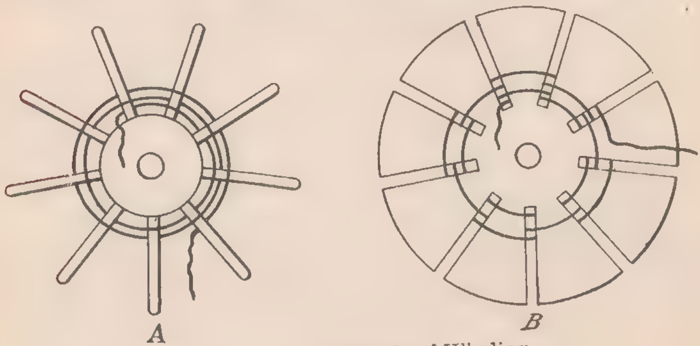


FIG. 7.—Two Methods of Winding.

similar manner, and the finished unit can be waxed or left as it is. It is, of course, impossible to remove the disc-former, which remains an integral part of the unit and serves to support it. The first method is advised when the wire used is thicker than No. 26 or a unit of fairly large diameter is desired. Those shown are wound with No. 26 gauge (fig. 8). The requisite number of units having been prepared, it only remains to string them on an ebonite or wooden rod and join up, being very careful to do this in such a way that the whole length of wire is going in the same direction, otherwise some units will be neutralising the effects of others.

As mentioned above, it is advisable to place a thin insulating disc between the units. These discs take up a little room, it is true, but the risk of rubbing away the covering of the wires is avoided, and condenser effects are greatly reduced.

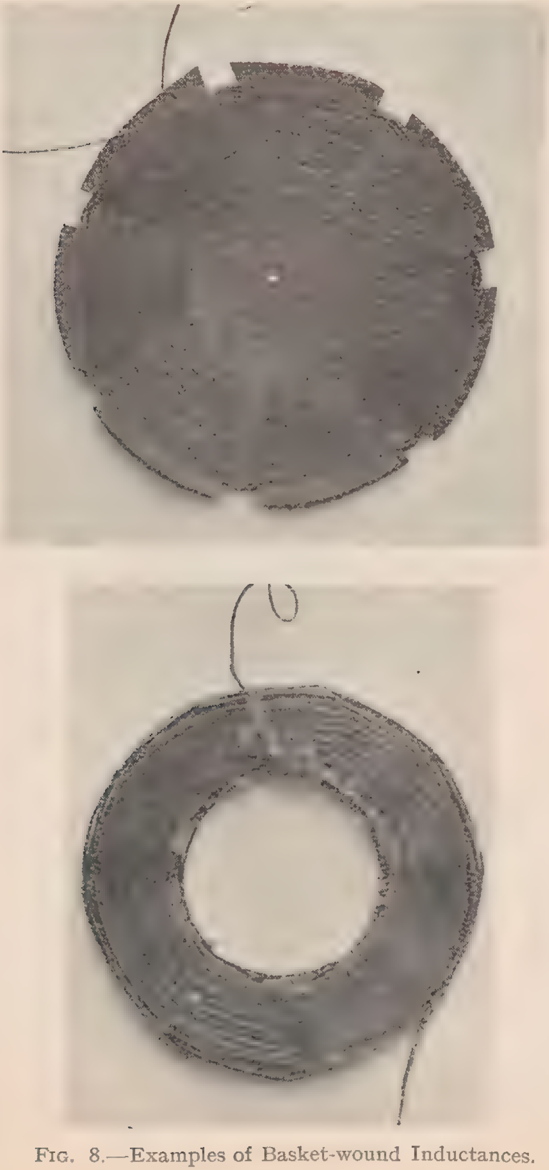


Fig. 8.—Examples of Basket-wound Inductances.

There is a modified form of pancake coil often spoken of as a "slab." In this type the wire is wound without special supports, and the coil maintains its shape by reason of the cementing action of the wax or other insulating medium incorporated in it. Detailed particulars of the construction of such coils will be found in Chapter XI.

A recent development in coil-winding produces what may

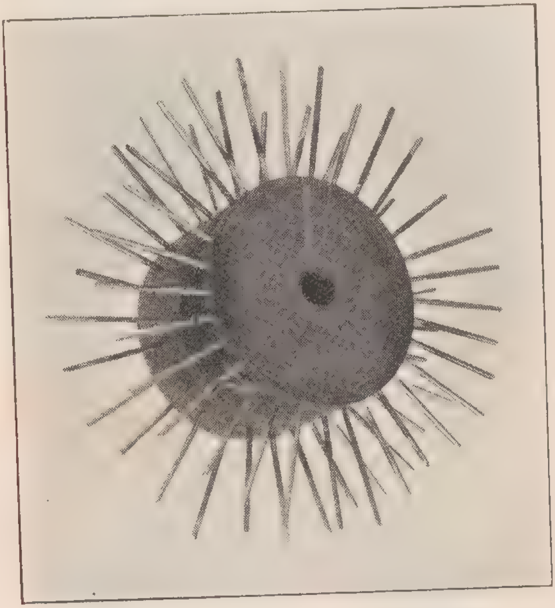


FIG. 9.—Former for winding Lattice Coils.

be termed, for want of a better explanation, a lap-wound basket coil. It is generally spoken of as a "lattice" coil. As some readers may wish to experiment a little in this direction, particulars are given of the method of construction. A mandrel of suitable dimensions is prepared and provided with a number of tightly fitting pegs or pins equally spaced and as near as possible to each edge. The example shown in fig. 9 is $2\frac{1}{2}$ in. diam. and $1\frac{1}{2}$ in. wide on the face. Each edge is marked off into thirty equal spaces and holes of suitable

size to hold the pins tightly, drilled in a radial direction as close as possible to the edges. No. 16 knitting needles form very good pins. They may be cut into pieces about $1\frac{1}{2}$ in. to 2 in. long, and if one end of each piece can be ground slightly taper as the original points are, they can be pushed in tightly and yet easily withdrawn. Now as to the method of winding. Suppose the pins to be numbered 1 to 30 and the two numbered 1 being axially opposite, then the wire passes from 1 (front) across the face of the mandrel in a slanting direction, round 17 (back), on in the same direction round 2 (front), on again

FIG. 10.—A Lattice Coil.

to 18 (back), and so on until a sufficiency of turns is laid on. The wire must not be stretched, but kept just taut, and pressed well into place. The whole is then immersed in melted wax until air bubbles cease to rise. The coil is then allowed to drain and cool, when the pins may be withdrawn. Fig. 10 shows a completed coil. It seems almost necessary to provide some sort of support for this type of coil, and it is suggested as the simplest means that thin silk ribbon be wound round it bandage fashion, the ends being stitched down, and the whole being given a couple of coats of shellac varnish. The advantages claimed for this type of coil will, however, probably not appeal to the average amateur, who will most likely content

himself with the simpler forms. It might be mentioned that in the former, illustrated in fig. 9, there are four rows of holes provided towards the back edge of the wooden mandrel. This allows coils of varying axial width being wound.

Now as to tappings from inductances. The easiest method when using a simple single-layer inductance is to use a slider; that is, a metal finger which can travel the whole length of the inductance and make contact with the wire at any point, a strip of the insulation having been removed for this purpose. Frankly, the writer does not favour this method. In order that contact may be positive, it is necessary for the finger to bear with considerable pressure on the wire, and, naturally, a good deal of wear takes place. Again, sliders rarely work with that smoothness of action possessed by a well-made radial switch. Then in the case of an inductance which moves within another, the slider method is out of the question. It is a far better job, mechanically and electrically, to divide the total inductance into sections, bring leads from these to a radial switch, and so link them in, in series, one by one as required. The sections need not be equal, *i.e.* one need not contain as many turns of wire as another. Generally the first stud of the switch brings into circuit somewhere about half the inductance, the next three or four about a tenth each, and then the remaining fraction of the inductance is further divided, even to a single turn of wire. For those who like an inductance of large size (from a range point of view) it is better to have a main inductance treated as above, and then three or four subsidiary inductances, each equal to about half the main, and to bring in these subsidiary inductances as complete units, making final adjustments by means of the subdivided main inductance. Tapping from a lap-wound or basket-form inductance must be done by switching, obviously. There is a peculiar charm in the smooth, gliding action of a well-made switch, and the contact is certain. The writer illustrates a home-made switch of the type meant, although it was not intended for wireless work (fig. 11). The switch arm projects further from the spindle on one side than on the other, and is formed of three or four laminations of hard brass, copper, or phosphor-bronze foil. The longer end sweeps over the studs, while the shorter bears on a brass disc. Contact is thus always assured.

Very large inductances are often joined up in various

combinations by plugging. That is, each end of the winding of each section is brought to a metal socket. Metal plugs with insulated heads are joined in pairs by short lengths of well-insulated flexible wire (lighting flex does admirably), and sections can be plugged in, in series, as desired. It has often been stated as an objection to the use of sliding contacts or switches as a means of adjusting the amount of inductance included that there is present what has been termed a "dead-end effect"; *i.e.* the unused end portion of the inductance, which is still, of course, in metallic connection with the part in use, acts as a small oscillatory circuit on its own account,

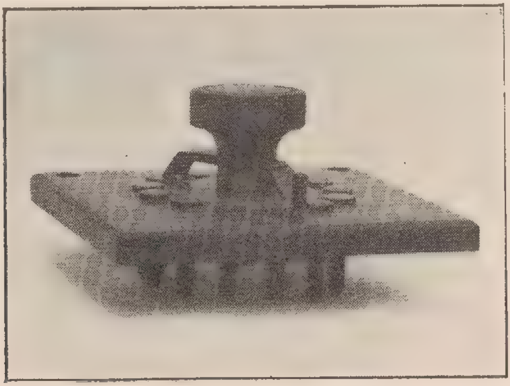


FIG. 11.—A Radial Switch.

and the effects of this circuit may have disturbing influences on the rest of the inductance. This is true in many cases. It is entirely avoided by the plugging method, as then an unused section is absolutely out of connection. Or it may be avoided by using a specially constructed switch, difficult to describe and requiring a good amount of care and skill in construction. Briefly, the two ends of each section of the winding, with the exception of the first, are brought to two small studs of metal, and these studs are arranged in pairs quite close to one another on the circumference of a circle. Within this circle a disc of ebonite, provided with a spindle and a milled head, can revolve. This disc has projecting from its edge metal tongues of such size and so placed that

each can in turn just span a pair of the studs. The first tongue, however, is but half the width of the rest, and is connected to the metal spindle and so forms one end of the amount of inductance in use. A little study of the diagram (fig. 12) will show how matters are arranged. Each successive movement of the switch-head joins one section and its neighbour in series, while the narrow tongue brings the end of that section to the terminal. If the switch is to be covered in, it is as well to have some means of indicating the position of the half tongue, in order that it may be known at any time how much of the inductance is in series. The writer has seen a similar switching arrangement where the tongue passed between springy blades of metal instead of pressing on studs. The reader must adopt whatever principle he prefers, but always remembering that the efficiency of a set can be reduced to an enormous degree by poor contacts at a switch. Use plenty of metal in the points of contact, have good rubbing surfaces, and solder, as far as possible, all joints or connections.

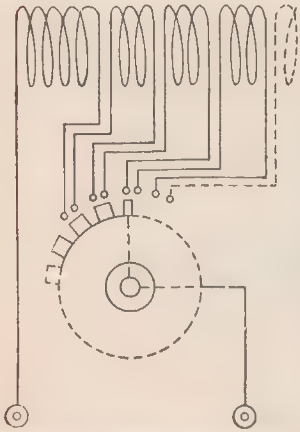


Fig. 12.—Switch for avoiding "Dead-end" Effects.

Now as to arrangements for "coupling." This is the degree to which two inductances can act mutually (inductively) on each other. It can be brought about in many ways. The simplest is to allow one inductance to pass within the other, the two windings being parallel and concentric. Or one may be fixed and the other rotate at right angles to it, or, as a modification, the main inductance may be divided into halves and the secondary rotate at right angles between them.

Again, the inductances may be wound in basket form and one set slide over the other or move on a hinge joint like the leaves of a book. In some cases one inductance is fixed and the other moves on a rod which is provided with telescopic and ball-and-socket movements. Here the relative positions of the inductances are infinitely variable. The reader will no

doubt be able to make a suitable choice for himself, having due regard to the peculiarities of his set and his own constructive ability. Coupling should be possible between zero and the maximum, making the necessary movement as simple and as easily obtained as possible.

Many amateurs find themselves in difficulties when they set about winding an inductance. They desire to know, within reasonable limits, what diameter their inductance-former must be, and how many turns of some particular gauge wire they must put on it, in order to produce an inductance of the desired value. Now, while the exact determination of inductance is a matter of some little difficulty, especially to the non-mathematical amateur, there is no reason why there should be any obstacles in his way when he requires but a fair approximation. The following formula, due to Professor Nagaoka, is the simplest method of finding the inductance of a single-layer coil wound on a cylindrical former:—

$$L = \pi^2 d^2 n^2 l K \quad . \quad . \quad . \quad . \quad \text{(i.)}$$

where L=inductance in cms.;
d=diam. of inductance in cms.;
n=number of turns per cm.;
l=length of coil in cms.;
K=the factor depending upon the ratio between diameter and length of the coil.

Or again,

$$L = \frac{\pi^2 d^2 N^2}{l} K \quad . \quad . \quad . \quad . \quad \text{(ii.)}$$

where N=total number of turns, the other quantities remaining as above.

The factor K is given for the most common ratios:—

$\frac{\text{diam.}}{\text{length}}$	=1,	then factor	=·6884
,,	=·75	,,	=·7478
,,	=·66	,,	=·7717
,,	=·5	,,	=·8181
,,	=·33	,,	=·8734
,,	=·25	,,	=·9016

The inductance of a basket coil may be calculated from the following formula, though the result is hardly likely to be so nearly approximate as in the case of the cylindrical coil, this being due mainly to the air-spaces:—

$$L=\pi^2 d^2 n^2 l \quad . \quad . \quad . \quad . \quad \text{(iii.)}$$

where L=inductance in cms.;
d=mean diam. in cms.;
n=number of turns;
l=difference between radii of outer and inner turns.

For a slab coil of average dimensions the following formula, adapted from one by Brooks and Turner, may be used:–

$$L=\frac{4\pi^2 a^2 n^2}{b+c+r}\times 1{\cdot}2 \quad . \quad . \quad . \quad \text{(iv.)}$$

where L=inductance in cms.;
a=mean radius of windings;
b=depth of coil (axially);
c=thickness of coil (radially);
n=number of turns (total);
r=outer radius.

As regards "lattice" and coils of similar type, the writer is not aware of any simple formula whereby the inductance value may be found by calculation. However, for a lattice coil of no more complicated winding than that described, the complete formula of Brooks and Turner (of which (iv.) is a simplified form) may be used:—

$$L=\frac{4\pi^2 a^2 N^2}{b+c+R}F_1 F_2 \quad . \quad . \quad . \quad . \quad \text{(v.)}$$

where L=inductance in cms.;
a=mean radius of winding;
b=axial length of coil;
c=thickness of coil (radially);
N=total number of turns;
R=outer radius;

$$F_1=\frac{10b+12c+2R}{10b+10c+1{\cdot}4R};$$

$$F_2={\cdot}5\log\left\{100+\frac{14R}{2b+3c}\right\}.$$

The above formula will produce results which, in this particular case, must be accepted with much reserve, as they are hardly likely to be more than a very rough approximation of the value.

The results from the above formulæ are in centimetres, so that if desired in microhenries they must be divided by 1000. It should be a simple matter to find from these formulæ practically any dimensions required. As an example: suppose it is desired to know what length of tubular inductance-former of 10 cms. diam. must be wound with No. 28 D.S.C. wire, in one layer, to give an inductance of 1200 microhenries.

$$\begin{aligned}
\text{Then, cms.} &= \text{mhs.} \times 1000 \\
&= 1{,}200{,}000 \\
L &= \pi^2 d^2 n^2 l \ (\pi^2 = 10 \text{ approx.}) \\
1{,}200{,}000 &= 10 \times 100 \times 484 \times l \ (\text{No. } 28 = 22 \text{ turns per cm.}) \\
\therefore \quad l &= \frac{1{,}200{,}000}{484{,}000} \\
&= 2 \cdot 5 \text{ cms.} \\
\therefore \text{ turns of wire} &= 2 \cdot 5 \times 22 \\
&= 55
\end{aligned}$$

The following table may be of use in working out the above and other formulæ. It gives, as will be seen, the number of turns per centimetre or inch of the wires most commonly used. Fractions of a turn would, of course, be omitted when the actual total for any length has been determined; and the values given are calculated on the assumption that the wires are as closely wound as is possible. For enamelled wire, the values assigned to single-silk covering may be adopted, though it is obvious that in this particular case the comparison may not be strictly true in all gauges of wire. It is, however, near enough for such calculations as the beginner is likely to make.

[TABLE .

Gauge S.W.G.	Turns.			
	Per cm.		Per in.	
	S.S.	D.S.	S.S.	D.S.
20	10	9·5	25·5	24
22	13	12·5	33	31·5
24	16·5	13·5	41	38·5
26	20	18·5	50·5	47
28	23·5	22	58·5	55·5
30	28	25·5	71	64·5
32	32	29·5	81	75
34	36·5	33·5	92·5	85
36	43	40	109	101·5
38	52	47·5	132	120·5
40	62	56	157·5	142

CHAPTER III

CONDENSERS

Our next consideration shall be that of condensers, and as these form a very important component of W. T. sets, both transmitting and receiving, the amateur who contemplates constructing his own will do well to let his condensers have the greatest care he can give.

A condenser, as most readers will be aware, consists of two conductors separated by an insulating material which is termed the dielectric. As the name implies, a condenser receives upon its conducting surfaces charges of electricity of opposite potential, *i.e.* opposite at any particular instant, and as its surfaces are usually much greater than those of the conductors connected to them, and owing, also, to the mutual attraction

between charges of opposite potential, there is at certain periods an accumulation of energy present in the condenser. It will be seen now, as was mentioned earlier, that two wires, though insulated, and, it may be, some little distance apart, can form a condenser. In fact, very tiny condensers are often quickly formed by twisting two pieces of rubber-covered wire together. The capacity can be rapidly adjusted by allowing more or less of the wire to be included in the twisted portion. As the energy dealt with in a receiver is of a high-frequency oscillating nature, it is imperative that the dielectric should be of high value. Indeed, it is essential that the whole insulation of a set shall be as good as can be obtained, this explaining the apparent lavish use of ebonite, and also the necessity for absence of damp and removal of dust. Condensers may be of two forms, fixed and variable. In a receiving set the fixed does not figure much, and those that do occur are usually of small capacity. Now, as the metal surfaces of a condenser, except for very small capacities indeed, require to be large in order to give sufficient area for the accumulated energy, a condenser of two simple metal surfaces only would be of very large size and consequently very cumbersome. It has been calculated that, even under the best conditions, a condenser of one farad (the unit) capacity would require plates having an area of several acres. The conducting surfaces, therefore, nearly always take the form of two sets of metal plates, each set having its plates connected in parallel. The efficiency of a condenser is governed mainly by two factors, (*a*) the value of the dielectric, and (*b*) the space separating the conducting surfaces. This means that the closer together the plates are, and the higher the insulating properties of the dielectric, total area remaining constant, the greater the capacity, and, if the term may be used, the stability of the condenser. Reduced to its simplest form, the whole question comes down to the fact that the thinnest possible dielectric should be used, consistent with safety.

The substances available as dielectrics are air, ebonite, glass, mica, or paper of close texture and well waxed to close its pores. Oil is also frequently used, and will be mentioned later. For fixed condensers, where the plates can be brought close together by pressure, mica is probably the best dielectric, but it must be specially selected mica. This substance, a natural mineral, can be obtained colourless and transparent through

many shades of colour to almost opaque. Frequently, too, in a specimen there will be streaks or irregular patches of quite a different colour to the rest of the piece. These differently coloured portions are generally inclusions of other minerals, many of them fairly good conductors of electricity. It would be incorrect to say that discoloured mica is unfit for service as a dielectric, but at the same time, unless the substance has been supplied for this purpose by a firm specialising in electrical mica, it should be viewed with suspicion. Then, again, some specimens of mica exhibit quite different characteristics, as a dielectric, according to whether they are or are not under pressure. For variable condensers, where pressure is practically nil, the writer considers mica quite unsuitable. At least, that is his experience. It is quite non-conducting, but a variable condenser containing it seems inconsistent in action. This is probably due to the foliated structure of the substance, the electrical charges causing the folia to separate slightly. A minor consideration is the fact that mica is brittle and wears badly under such conditions. Ebonite is excellent provided it can be obtained thin enough, and uniform as to thickness. Each piece must be rigidly scrutinised for pinholes, and such pieces rejected. The writer has tried very thin presspahn (8 mils. thick), and finds that if waxed it answers well. A really good paper, also, if similarly treated, is quite serviceable.

Regarding the metal surfaces of the condenser, little need be said. For fixed condensers, unless they are of a very large capacity, or are required to stand very strong charges, nothing is better than stout tinfoil. For wireless work, a good margin should be allowed round the foil, and the whole condenser should be squeezed up as tightly as possible and either varnished or well soaked in wax to prevent ingress of damp. Most text-books supply information which will enable the reader to estimate within fair limits the capacity of a fixed condenser. The question of calculations as to dimensions and capacities of condensers is, however, referred to at fair length at the end of this chapter.

It may be of interest to mention a form of condenser not often used by amateurs. This is the Mansbridge type. Briefly, it consists of two strips of thin paper, each coated with a film of metal, rolled up very tightly and embedded in a solid block of wax, the whole being contained in a metal case. A con-

denser of very large capacity can be so made and yet be of very small dimensions. The writer possesses one of 2 mfds. capacity, measuring $5 \times 4{\cdot}5 \times 3{\cdot}5$ cms. over all (fig. 13). Their stated capacities are correct to within small limits, and they may, therefore, be used as standards for approximate comparisons. It is very useful to have a fixed condenser, the

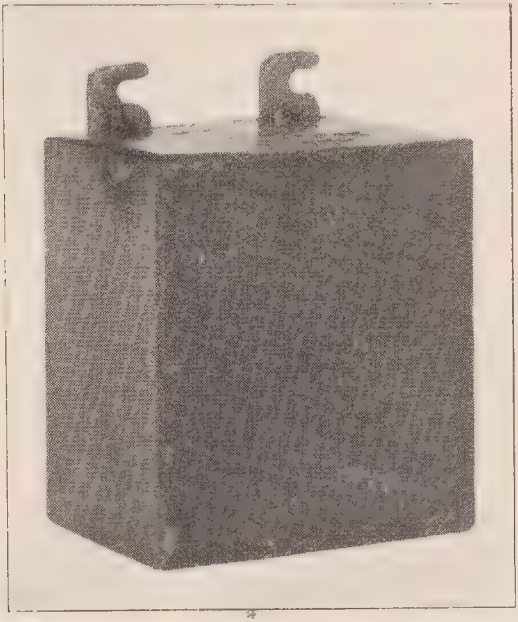


FIG. 13.—A Mansbridge Condenser.

capacity of which can be varied in certain fixed proportions. One can easily be made up, tappings from one side being taken by metal ribbons from certain points, and these tappings connected to a plug switch on the lid of the containing case. If the values of the sections can be fairly accurately determined and marked on the lid, the amateur will have an exceedingly useful accessory to his apparatus. The plug switch may be replaced by one of rotary type if desired, and this form is certainly quicker in operation than the former. Great care

must be taken, however, to ensure that really good metallic contact is made. Fig. 14 shows one method. Here a metal sector mounted on ebonite is made to bridge a series of studs, each one of which is connected to one side of the condenser sections. At the same time, this sector is always in contact with the first stud. Thus this latter stud forms one terminal of the total condenser in use, the other being the common lead from the other sides of the sections. The great difficulty with this type is that very accurate workmanship is necessary to ensure good contact, though this could be obviated by using spring studs, such, for instance, as the little spring plunger contacts used in lampholders. The writer prefers a barrel type of switch. One such is illustrated in fig. 15. Here the metal sector is replaced by a metal surface on the edge of an ebonite disc, and the studs by phosphor-bronze springs pressing against the edge of the disc. This form of switch works very smoothly, and as each spring is quite independent in action, any little inequalities are taken up, and contact is always certain. This method of putting condensers in parallel should be of interest to those amateurs who find the cost of fairly large variable condensers an obstacle. Many experimenters, too, when trying out circuits often find themselves hung up by want of one or more extra variable condensers. Now, if a fixed condenser of four or five sections be made up and joined in parallel with quite a small variable condenser, the difficulty is gone. The small variable can be used alone, or as a critical adjustment to one or more of the sections of the fixed condenser as desired. As small variable condensers of first-class construction can be purchased ready for use at a cost of five or six shillings, this method of procedure has much to recommend it.

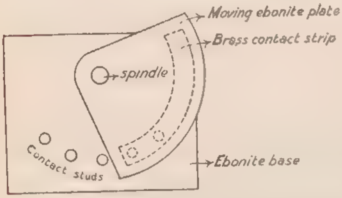


FIG. 14.—Switch for Condensers in parallel. (Radial type.)

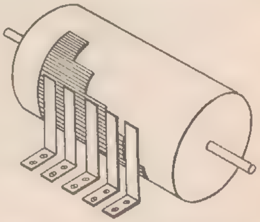


FIG. 15.—Switch for Condensers in Parallel. (Barrel type.)

Now as to variable condensers. And the writer means, of course, variable without fixed steps between zero and the maximum capacity of the particular condenser. Most readers will know the principle. Two sets of plates are made to interleave, insulation between them being maintained the while. There are various methods of constructing this type, and the amateur who looks with some misgivings upon the prospect of making his own may, it is hoped, be encouraged to proceed. The very best are those beautiful examples of workmanship where the two sets of plates are each produced from a solid block of metal, the dielectric being air or oil. Few amateurs are likely to attempt this form of construction, however, the general procedure being to cut the plates from thin sheet metal and then build these up into sets. Thin zinc, aluminium (or the aluminium alloys), copper, or brass are suitable. Tinplate is not suitable, unfortunately. The writer has used all the metals mentioned, and for preference likes zinc, provided it is free from dents or badly distorted places. No. 3 zinc is a good gauge for this purpose. It should be noted that zinc, like lead sheet, is gauged by weight per area, and not as other metals by direct thickness measurement. In the case of copper or brass, hard-rolled foil of about No. 36 S.W.G. is a suitable material. The plates, or, as they are generally termed, "vanes," should be marked out and then can be cut out with narrow-nosed snips or a stout pair of scissors. It is just as well to make a template of stout tinplate, as marking-out is done more expeditiously, and the template will also act as a jig for drilling the necessary holes, or final trimming into shape.

Variable condensers of the built-up type may be broadly divided into two groups: (1) those in which there is one stationary set, and (2) where there are two stationary sets. The first group may be subdivided into those where air is used as a dielectric, and those where discs of some insulating material are used as such. In the second group, discs are always used. The illustrations appended will, it is hoped, help considerably to make clear details of construction not quite easy to describe by words alone. It is not claimed that the sizes given are of necessity the best; they are given as they are available, and will convey some idea of proportion. Fig. 16 shows the shape and proportions of the components of a built-up condenser of the first group, (*a*) being the stationary vane, (*b*) the movable; while the photograph which the writer

is able to give should supply details of construction (fig. 17). The aim in a condenser of this type should be to let the vanes come as close together as possible, though contact in any place

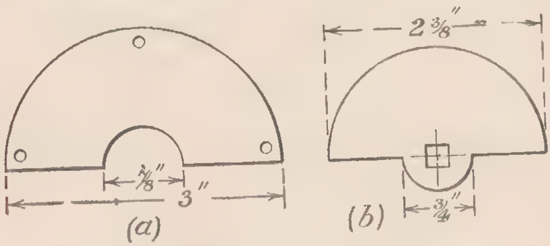


FIG. 16.—Components of a Built-up Condenser.

would, of course, be fatal. The vanes on each set are separated and electrically connected by brass washers. The thickness of these washers governs the air-space between the interleaved vanes. The rotating vanes are best mounted on a square

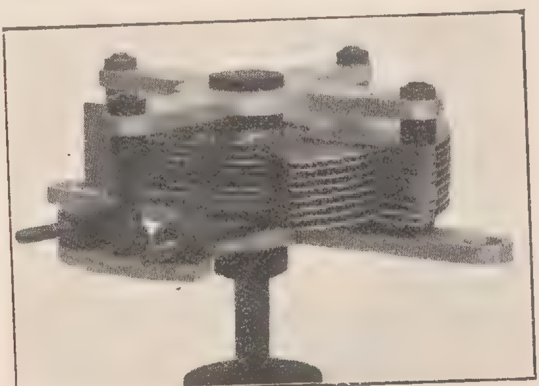


FIG. 17.—Variable Condenser with Air Dielectric. (Inverted to show detail clearly.)

spindle, so that shifting of any one vane is avoided, and at the same time the necessity for clamping them up with excessive tightness is obviated. It is usual to let a narrow strip of brass or copper extend the whole length of the fixed set of vanes at one edge, so that this acts as a stop to the movable set and

actually short-circuits the condenser just beyond the zero and maximum capacity points. The number of vanes is, practically speaking, unlimited; though, using the sizes shown, a condenser with about thirty fixed and twenty-nine movable vanes will be found of ample size.

Unless the reader specially desires to do so, it seems hardly worth while, nowadays, to construct a variable condenser right out. Sets of parts —vanes, fixed and movable, spacing washers and square spindles—are largely advertised, and will be found to be true to size and shape. They are, moreover, quite cheap and make up well. The one outstanding advantage with these vanes is that they are really flat, and the beginner is saved the difficult task of cutting and drilling vanes from the sheet, and at the same time keeping them flat. The writer has done this many times, and can speak from experience. Very serviceable variable condensers can be made by mounting sheets of tinfoil on thin hard card of the kind used for visiting cards, and proceeding as follows:—The cards (about 5 in. by 4 in. is a very good size) should be varnished on both sides with thin shellac varnish, and a sheet of foil 5 in. by 3 in. placed in position on one side of each before the varnish is quite set. Rub it down well, so that as much air is excluded as possible. Then varnish the foil. Now place a ½-in. strip of the same card across the lug end of each sheet, sticking it down with varnish (fig. 18). Do this with nine or eleven cards. When all are quite dry make them up into two banks by cementing with varnish on the ½-in. strips, all the foils being uppermost. Place the cemented ends under fair pressure and set aside until the varnish is quite dry. Now one set of cards can be made to interleave with the other, and if a strip of paper be fastened round the sides of the outer set, there will be no tendency for the inner set to get out of place. The projecting lugs of foil should be

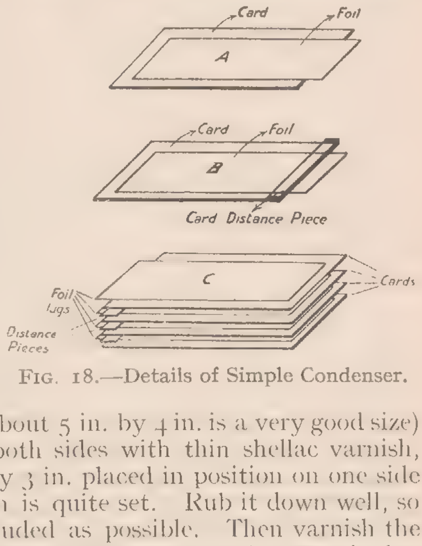


FIG. 18.—Details of Simple Condenser.

fastened together with small bolts and nuts and two strips of thin brass or copper to prevent the foil being torn. Fig. 19 gives an idea of the finished condenser, though, for the sake of clearness, the cards are shown widely separated.

Many amateurs seem to err on the side of over-condensing their sets; for it must always be remembered that the turns of wire on an inductance, generally a good number, all go to increase capacity. Generally speaking, too, the closed circuit will require a much smaller condenser than the aerial circuit, for the above reason. For a valve set very much smaller condensers still may be necessary, so that, to save material and time, a condenser should be built to suit as far as possible the circuit in which it is to be included. Condensers of the

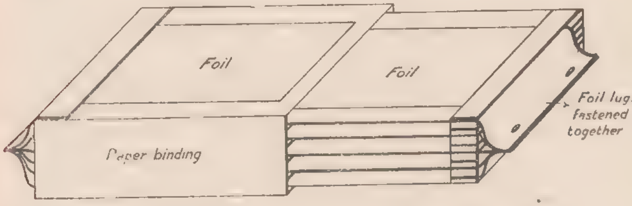


FIG. 19.—Sketch of Simple Condenser.

above type may be placed in a metal container and so totally immersed in oil. Transformer and castor oils are about the best for this purpose. It is important to remember that in a condenser where air is the dielectric, dust is a deadly enemy, and the sets of vanes should therefore be boxed in, making the whole thing as air-tight as possible. The milled head (which should be of ebonite or fibre) of the spindle should be marked with at least two points, zero and maximum; and it is very convenient to have the space divided into some number of equal divisions for the sake of reference. The above construction may appear a little beyond many amateurs, and it must be admitted that some skill and no little care are required to carry out the job successfully. A variation of this method is, therefore, offered where the two greatest difficulties, *i.e.* the correct spacing of the two sets of vanes, and the consequent necessity for their being absolutely flat, are avoided. The procedure is exactly as just described, with the difference that the vanes are spaced a little further apart, and each

moving vane is sandwiched by a pair of discs of very thin ebonite, stout waxed paper, or thin presspahn. These discs are just a trifle larger in diameter than the movable vanes, and have a central hole just large enough to allow them to slip over the washers separating these vanes. It will be seen that there is no possibility whatever of any of the vanes touching others in whatever position they may be. The condenser becomes a little more bulky and a little heavier, but these are small points. The writer once constructed a condenser on exactly the above method, but had to use mica for the separating discs. The vanes were of hard-rolled copper, and the whole concern took a surprisingly short time to complete. It might be mentioned, too, that the tools available were very few, and not fine ones by any means. As a condenser it was for some time quite satisfactory, though the continual rubbing produced a large quantity of fine dust and its behaviour became rather freakish. The mica has since been replaced by very thin ebonite, with very marked improvement.

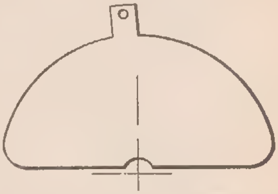


FIG. 20.—Outline of Fixed Vane.

The remaining type, viz. that having two sets each of fixed and movable vanes, is a very interesting one, but probably the most difficult of construction. Those readers who are at all familiar with Marconi instruments will recognise the description. Its construction and action are not quite easy to describe.

A brief inspection would enable both to be grasped at once. All the vanes are of identical shape and size, and instead of being moved from the centre, the rotating vanes are moved from their edges by means of a projecting lug. An ebonite rod running right through the axis of the condenser causes the vanes to retain their correct position. Ebonite, in the form of very thin discs, is used as the dielectric. Each disc is of the same diameter as a pair of vanes when in position, and is slipped over the central ebonite rod, being provided with a central hole for that purpose. From the diagrams it will be seen that the projecting lugs are a little to one side of a line at right angles to the straight edge of the vanes. The fixed vanes are held together and kept stationary by their lugs (fig. 20). When the condenser is standing at zero

capacity, there are two sets of vanes on either side. Let us suppose those on the right have a positive charge, and those on the left a negative. Now, as rotation commences, the movable positives and negatives start to leave their fixed companions and begin to interleave with the fixed vanes of opposite polarity. The proportion of interleaving, and consequent

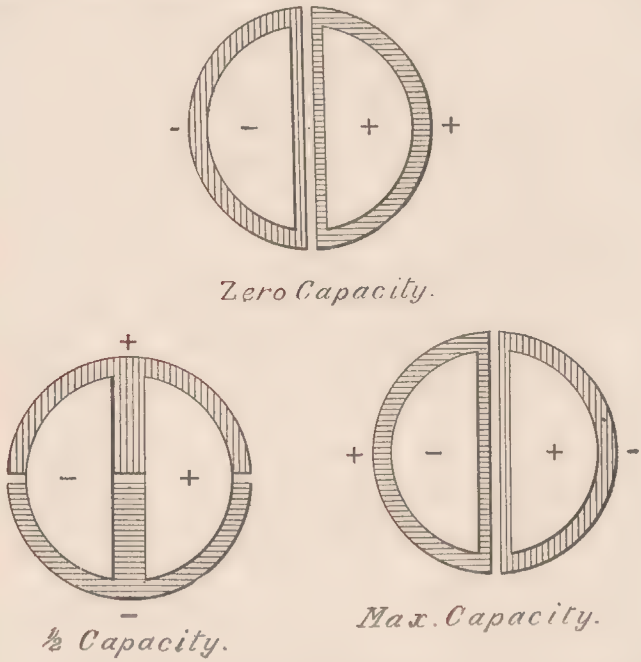


FIG. 21.—Showing relative positions of Vanes for various Capacities.

increase of capacity, continue to get larger until the maximum has been reached, when the movable vanes from the right are now completely interleaved with the fixed vanes on the left, and *vice versa* (fig. 21). A moment's consideration will show that a condenser of this type has twice the capacity of one of the former, when the area of the vanes is similar and the number on either side is the same. These condensers are very efficient, and the frictional effects in them prevent disturbance

of adjustment by an accidental touch or a jolt to the set. The writer has made some of similar type, but of very small total capacity, for use in some experimental valve sets.

It sometimes happens that a condenser is required where very tiny adjustments are necessary, and recourse is had to what are termed "billi" condensers. Generally, these take the form of a metal tube sliding within another. The tubes may be so mounted and of such size that the air-space between them acts as the dielectric; or the inner one may have a covering of well-waxed paper, celluloid, or ebonite. The movement of the sliding tube can be done directly by a projecting knob, by a feed screw, or even by rack-and-pinion arrangement. A projecting finger may be made to pass over a scale and so provide an indication of the amount of surface actually in service. The writer came across, some little time back, a type of condenser with air dielectric which was quite new—to him, at any rate. The idea is good, and construction does not seem to be very difficult. The diagram (fig. 22) will help the explanation of the action. The plates consisted of curved sheets of metal resembling semicircular troughs. They were of varying diameters, and so arranged that one set gradually interleaved with a second set, these latter being fixed. Correct alignment was assured, as the lower edges of the moving plates slid in circular grooves cut in the ebonite base. It would seem pretty simple to construct such a condenser if one could obtain a range of tubes of varying and suitable diameters, and slit them up on either side.

FIG. 22.—Diagram of Condenser built up of Plates of Semicircular or Trough Cross Section.

To sum up, then: variable condensers may be considered as indispensable in a receiving set, and should be as good as can be obtained. The amount of capacity required in a receiver circuit, either aerial, closed, or intermediate, can be provided in one of two ways: (*a*) by a variable condenser with sufficient maximum capacity, or (*b*) by a block or fixed condenser of almost the maximum capacity likely to be required, together with a small variable condenser joined in parallel with it. Where any critical adjustments are necessary,

a billi condenser may also be connected in parallel with other condensers in the same circuit. One little fitment often omitted by amateurs is a small spark gap across a condenser. Two metal points, so arranged that they come together within half a millimetre or so, is all that is required. The dielectric of condensers being cut down to the irreducible minimum is easily broken down by a sudden strain such as may be produced by severe "atmospherics." The safety-spark gap, then, provides a sufficient path for such high-tension discharges, and the condenser is saved from disaster.

Having discussed types of condensers and their construction, it is necessary to say a little as to the calculations that have to be made in order to produce a condenser of definite capacity. Judging from the queries so often made on this subject, there would seem to be some considerable lack of knowledge amongst beginners on the question. Most good text-books give formulæ whereby the capacity of a condenser may be estimated, but it is quite likely many beginners are a little dubious about tackling what seems to be a rather abstruse mathematical problem. The three main factors determining the capacity of a condenser are: (*a*) the area of the opposing conducting surfaces, (*b*) the nature of the dielectric, and (*c*) the thickness of the dielectric. In making calculations, then, it is important to remember that in a fixed condenser only the actual overlapping surfaces of the metal sheets must be measured; and in the case of a variable condenser, with semi-circular plates, the diameter of a small plate must be taken as the basis of calculation. The nature of the dielectric is really of much more importance than that of the metal surfaces, for it is a demonstrable fact that the charges of electrical energy are not on the metal surfaces, as might be supposed, but on the surfaces of the dielectric. Then, again, as the accumulated energy may reach considerable proportions, it is evident that the physical properties of the dielectric will enter largely into the question; as it is quite possible, for instance, that the electrical strain existing may produce marked changes in the properties of the dielectric. The thickness of the dielectric, too, may be a very fictitious value, as much depends upon the pressure applied during the building up of the plates and sheets of dielectric. In the case of a solid dielectric, air may be present, or the introduction of some binding material such as wax or varnish may produce quite a different value.

The formula most generally used in calculating capacity is :—

$$C=\frac{A\times K}{4\times\pi\times d\times 900{,}000} \quad . \quad . \quad . \quad \text{(i.)}$$

where C=capacity in microfarads ;
A=area of one set of metal surfaces, in square centimetres ;
d=distance separating plates in cms. ;
K=dielectric constant.

If the result is desired in centimetres, the factor 900,000 should be omitted from the denominator, as 1 mfd.= 9×10^5 cms. (or electrostatic units).

Results from this formula are closely approximate in the case of fixed condensers, but not quite so exact in the case of variable condensers, as those with semicircular vanes do not always strictly conform to rule, and, especially where banks of vanes are used, no account is taken of what is termed the "edge effect." This latter consideration, however, the beginner may neglect from his calculations. The dielectric constants for the materials in common use are given in the following table :—

Glass	8	(photographic plates)
Mica	6	
Shellac	3	
Presspahn	3	(average specimens)
Ebonite	2·5	
Paraffined paper	2·5	(good hard paper)
Celluloid	1·5	
Air	1	

Suppose now, for example, it is required to build up a fixed condenser of 0·002 mfd. capacity, using tinfoil and mica 0·01 cm. thick, what size sheets of foil will be required, and how many ?

$$\text{Then} \quad C=\frac{A\times K}{4\times\pi\times d\times 900{,}000}$$

$$\therefore \quad 0{\cdot}002=\frac{A\times 6}{4\times 3{\cdot}14\times {\cdot}01\times 900{,}000}$$

$$\therefore \quad A=\frac{{\cdot}002\times 4\times 3{\cdot}14\times {\cdot}01\times 900{,}000}{6}$$

$$=38 \text{ (approx.)}$$

Now 38 sq. cms. may be allotted in any manner convenient. Thus four sheets each 4 cms. by 2·4 cms. will give the necessary area, so that a total of eight sheets must be prepared, always bearing in mind that actual opposing surfaces only have been settled; therefore extra length must be provided to give projecting lugs for connections. So that eight sheets of foil each 6 cms. by 2·4 cms. will be about right, this leaving 2 cms. as lugs.

The same procedure exactly may be adopted for ascertaining the number of vanes necessary to build a variable condenser of some desired capacity. Take the diameter of one small —or movable—vane and calculate its area as a circle, thus including both sides:—

$$\text{Area} = \frac{\pi \times d^2}{4} \quad . \quad . \quad . \quad . \quad \text{(ii.)}$$

Next find the *total* area required to give the capacity desired, and divide this area by the area from (ii.). This, to the nearest whole number, will give the number of movable vanes required; and consequently the same number, plus one, of fixed vanes will be necessary.

Amateurs frequently desire to build variable condensers of the tubular pattern, where two metal tubes slide one over the other, the dielectric being either a small air-space or a thin tube of some insulating material such as ebonite or celluloid. Such a condenser is often very useful, especially in valve circuits, as very fine adjustments indeed are possible by its use. Mention has been made of it earlier under the name of a "billi" condenser. To determine the capacity of this type the best formula is probably

$$C = \frac{\frac{1}{2}K}{\log \frac{D}{d}} \times l \quad . \quad . \quad . \quad . \quad \text{(iii.)}$$

where C=capacity in cms.;
K=dielectric constant (of material between tubes);
D=diam. of outer tube in cms.;
d=diam. of inner tube in cms.;
l=length of effective surface in cms.

(Divide result by 900,000 to reduce to mfds.)

For example, what is the capacity in mfds. of a tubular condenser where the diameters of the outer and inner tubes

are 3·2 cms. and 3 cms. respectively, the effective length being 12 cms., there being an air-gap of 0·1 cm. between them?

Then
$$C=\frac{\cdot 5}{\log \frac{3\cdot 2}{3}}\times 12$$

$$=\frac{\cdot 5}{\log 1\cdot 066}\times 12$$

$$=\frac{\cdot 5}{\cdot 0277}\times 12$$

$$=216\cdot 6 \text{ cms.}$$
$$=0\cdot 00024 \text{ mfd.}$$
$$216\cdot 6 \div 900{,}000.$$

One sometimes comes across capacity expressed in terms of "jars" This term is largely used by marine radio-engineers and is derived from the fact that condensers, especially those used in transmission sets, are often constructed in the form of a Leyden jar. For all practical purposes it may be taken that 1 jar=0·001 mfd.

As mentioned earlier in this chapter, a good deal can be done in varying capacity by connecting two or more condensers in series or parallel. If they are connected in series the total capacity is diminished, the result always being less than that of the smallest condenser in the series. If they are joined in parallel then the total capacity is the sum of the individual capacities; for it is obvious that in this case we are really forming one condenser of increased plate area (figs. 23 and 24). Beginners often seem puzzled to know what is the resulting capacity of series-connected condensers. The rule for determining this is, "the reciprocal of the total capacity is equal to the sum of the reciprocals of the individual capacities." Or it may be expressed:—

$$\frac{1}{K}=\frac{1}{K_1}+\frac{1}{K_2}+\frac{1}{K_3}+\ldots\frac{1}{Kn} \qquad \text{(iv.)}$$

where K=the total capacity,

$$\left.\begin{matrix}K_1\\K_2\\K_3\\Kn\end{matrix}\right\}=\text{capacities of individuals forming the series.}$$

For the non-mathematical reader a simple way of resolving this formula is as follows:—Reduce the several capacity values to vulgar fractions, invert these fractions and find their sum. Invert the sum and convert the resulting vulgar fraction to

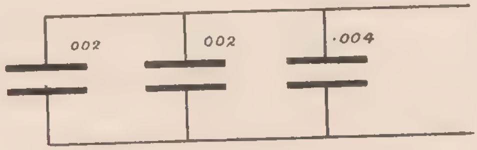


FIG. 23.—Condensers in Parallel.

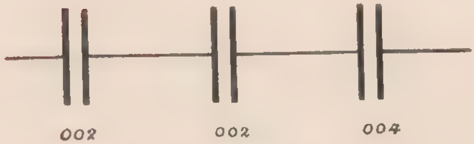


FIG. 24.—Condensers in Series.

a decimal. For example, in fig. 24 we have three condensers of 0·002, 0·002, and 0·004 mfd. capacity respectively. If joined in series, what is the resulting capacity?

Then $$0{\cdot}002=\frac{1}{500}\ (\text{inverted}=500),$$

$$0{\cdot}004=\frac{1}{250}\ (\text{inverted}=250).$$

Then $$500+500+250=1250\ \left(\text{inverted}=\frac{1}{1250}\right).$$

And $$\frac{1}{1250}=0{\cdot}0008\ \text{mfd.}$$

CHAPTER IV

DETECTORS

Having provided an aerial circuit to receive incoming wireless oscillations, and possibly a closed circuit whereby they may be tuned or sharpened up, or, so to speak, sorted out, it is necessary to provide a means of detecting them, or, in other words, making them appreciable to the senses. The raw beginner might, pardonably, suppose this could be done by some sort of galvanometer or similar instrument. This, however, is not possible, except in the case of one special form of galvanometer, mainly because the oscillations are of such high frequency, and also because most galvanometers possess, by reason of their construction, a good deal of inductance and very often considerable resistance. The exception referred to is the Einthoven, or, as it is sometimes termed, the "string" galvanometer. This instrument is worthy of some mention, though few amateurs are likely to possess one, and fewer, possibly, will attempt its construction. Briefly, it consists of a very powerful electro-magnet, the poles of which are brought very close together. In the very small space between the poles is stretched a very fine conductor, which generally takes the form of an exceedingly thin fibre of quartz, which has been silver-plated to render it conducting. Now, on the passage of current through (or rather on) this fibre, it (the fibre) is surrounded by a small magnetic field. But magnetic fields attract or repel one another according to their polarity. Consequently, the fibre becomes bowed out from its original straight position, the amount of bowing depending upon the strength of the magnetic field surrounding it. In those cases where the received waves are of an oscillating nature the fibre is bowed backward and forward in accordance with the oscillations. The result is a kind of twitching on the part of the fibre. A beam of light is made to pass through a hole bored in the poles of the electro-magnet, so that a shadow of the fibre can be photographed on a moving sensitive film. Consequently, a permanent record of the movements of the fibre is obtained, and if the rate of the movement of the film is known, actual calculations of the frequency of the received oscillations can be made.

In the early days of wireless work it was customary to use

what was known as a "coherer." The oscillations were made to pass through a form of resistance which they had the power of modifying or breaking down; and a local current passing through the modified resistance was caused to give some audible or visual signal.

Coherers have long since passed to the realms of superseded scientific curiosities, as they proved to be slow, unreliable, and sensitive only to the strongest oscillations. The magnetic detector is an interesting piece of apparatus, though hardly likely to come within the amateur's range. In this, the oscillations are made to vary the magnetic condition of an iron wire passing close to the poles of a strong magnet. The wire is endless and is made to travel at a fairly slow speed by a clockwork arrangement. The varying magnetic fields in the wire set up induced currents, which, in turn, are made to influence a telephone receiver, the result being audible signals. The wire is finally relieved of its magnetic strains by passing further magnets which neutralise whatever magnetism may be remaining in it. This form of detector is still largely used in commercial working, especially on board ship, as it is robust and requires the minimum of attention. The electrolytic detector was at one time largely used, being, in fact, fitted to some forms of commercially made receiving sets. Here the oscillating current is made to break down the polarised condition of a metallic couple immersed in an acid or strong alkaline solution. A tiny vessel, generally of lead, contains some dilute sulphuric acid, and dipping into this is an exceedingly fine platinum point. The lead cup and platinum point are placed in a circuit of small potential. At first current is able to pass, but very soon a sort of non-conducting film of gas forms around the point, completely preventing the further passage of current. Now, those oscillations, passing in the opposite direction to the local current, cause a momentary breakdown of the non-conducting film. Consequently, the applied current is able to flow for a very short period. These little pulses of current were generally made to actuate a delicate relay, which, in its turn, rendered the signals readable.

Nowadays the telephone receiver is practically universally used to make the signals audible, as a properly designed telephone is exceedingly sensitive to the very minute currents, and messages are far more easily followed by ear than visually. It might be supposed that oscillating energy could be made

to influence a telephone receiver directly. This is so, except that in the case of wireless work the oscillations are of such high frequency that it is very doubtful whether the diaphragm of the telephone receiver could vibrate quickly enough, and even if it were capable of doing so the sound produced would be far beyond the power of the human ear to appreciate. It becomes necessary, therefore, to employ some means of breaking up, or modifying in some way the oscillations received. It has been found that many substances when in a crystalline condition have, from some more or less obscure reason, the power or property of allowing current to pass through them more readily in one direction than the other. That is to say, they act in much the same manner as a non-return valve does with water or steam. What really happens is, the positive (or negative, as the case may be) halves of the oscillations are prevented from passing the crystal, so that the sounds heard in the telephone receivers are the totals of small groups of half oscillations. For this reason such crystalline substances are often termed rectifying detectors. Such substances are mostly natural products, that is to say, mineral substances in crystal form, though quite a number of artificial crystals have been produced having the same properties. As this method of detection will, no doubt, be that adopted by the majority of beginners it is proposed to devote a little space to the subject of crystal detectors. First, as to the substances available. The writer was going to say their name is legion. Certainly there is a great number, and it is quite possible there may be many others not yet discovered, so there is plenty of scope for experiment. Many amateurs who have had some experience will, no doubt, continue with their old favourites, for most pre-war workers were prepared to swear by some particular combination or other. The writer will, therefore, endeavour to cover the subject as impartially as possible. Most amateurs will probably get their crystals from a firm specialising in wireless apparatus and accessories, and if they do not desire to experiment with little known or seldom used material, this will probably be the better plan, for such crystals are usually selected for the purpose and have generally been tested for suitability. Those who desire to do a little original work or find any difficulty in obtaining a particular specimen should apply to a good mineralogist. The writer can, with every confidence, recommend J. R. Gregory & Co., of 139

Fulham Road, South Kensington, S.W.3. This firm has a very extensive stock of all classes of material and will supply the smallest quantity.

Bearing in mind the fact that wireless telephony is received quite well by a crystal detector, and also that we may expect enormous developments in the wireless transmission of speech and music in the immediate future, the reader will see that the crystal still holds a very useful, and even important, place in wireless apparatus.

Crystals, whether natural or artificial, may be roughly classified in several ways; some require a small current applied to them to bring them to their most sensitive condition; some are very sensitive, but rather unstable, *i.e.* they are easily put out of action by excessive currents passing through them, or even by disturbances set up by local high-tension discharges. Others, again, while not so sensitive, are quite robust; some work better when in contact with another kind of crystal, and some are best used in contact with a metallic point. The pressure at the point of contact is often an important factor. In any case, it is far better to use a naturally fractured surface than to attempt any trimming, such as grinding or filing. Most readers will be aware that the majority of crystalline substances will, if struck, break more easily in certain directions than in others; that is, they have definite planes of cleavage due to their crystalline structure; and crystals are generally in their most sensitive condition when such natural faces, or the angles produced by such faces, are used. Again, scrupulous cleanliness must be observed with a newly-fractured crystal, even the touch of a "clean" finger being sufficient to detract from its best condition. All manipulation should therefore be carried out with a pair of clean tweezers. Some method of mounting the crystal is necessary. Most crystals are but poor conductors, and so a good surface should be presented for connection to the holder. The commonest, and perhaps the best, method is to embed the crystal in a small brass cup, the hollow of which is filled with a metallic alloy having a low melting point, such as Wood's alloy. This material is best obtained ready prepared, as its preparation requires some little care. It is fairly expensive, but a small quantity goes a long way, and that already filling a cup may be used many times for further crystals, adding a little fresh if necessary. Some amateur

workers like a large crystal, but the writer believes this to be generally speaking bad practice. To be sure, a very small crystal needs very delicate handling to mount successfully, but this is merely a matter of practice and patience. In most cases a small fragment is generally of greater purity and has much better crystalline characteristics than a relatively large piece, even of the same specimen. Then again there is the matter of resistance to be considered.

The ideal crystal or crystal combination should possess, as far as possible, the following properties:—(1) Rectification should occur with the smallest possible current differences; (2) the crystals should be robust, *i.e.* not very friable or brittle, as a certain amount of wearing away is inevitable; (3) they should be constant in action, or in other words, not unduly affected by the current passing through them; (4) they should be unaffected by atmospheric conditions, that is, they should not easily oxidise or be subject to decomposition, and (5) what is very important where transmission also is practised, they should not be affected by neighbouring electrical discharges. The writer has found some varieties of carborundum very susceptible in this respect, and would advise readers when purchasing carborundum for detectors to closely observe its characteristics; the best, for all-round purposes, is that with a peculiar greenish-grey, glassy appearance. Next best is that of a steel-grey, almost black colour, with very bright, shining crystal faces. The dull-grey or highly coloured specimens are practically worthless to the wireless man.

Some little doubt seems to exist as to whether crystals are damaged, or otherwise, by the heating during their setting, and many forms of clamps, etc., have been devised to do away with the fusible alloy bedding. Personally, the writer believes that if the alloy is rendered just fluid enough to be worked easily, no harm results to the crystal. He has often heard it said that a "good warm-up" revives a crystal, and, indeed, has seen it done. But heating may, and often does, alter the physical and chemical properties of some crystals, so that it would seem the better plan to avoid anything like great heat. Wood's metal melts well below the boiling point of water, so that by using this alloy undue heating should not occur. The writer, also, does not quite hold with the practice of securing a crystal between two metal springs, except in certain cases. It is quite feasible that the particular crystal in use may, with

the metal composing the springs, form in themselves local rectifying points, and that such points may modify or even neutralise the actual combination desired.

A list is given of materials which have been used, and they are roughly classified as some little guide to their properties. The list is by no means complete and does not include materials sold under certain trade names. These latter will be found in some cases to be merely natural materials of exceptional purity or crystalline perfection. The common mineralogical name is given and also the chemical composition corresponding to the absolutely pure equivalent. Those marked with an asterisk are either artificial or have undergone preparation.

Robust.

Bornite, $3Cu_2S_3$. Fe_2S_3 (Erubescite).
*Carborundum, SiC.
Corundum, Al_2O_3.
Copper pyrites, Cu_2S. Fe_2S_3 (Chalcopyrites).
Hæmatite, Fe_2O_3.
Malachite, $CuCO_2$. CuH_2O_2.
Pyrites, FeS_2.
Pyrrhotite, FeS.
Octahedrite, TiO_2 (Anatase).
*Silicon (fused), Si.
*Zirconium, Zr.

Brittle.

Blende, ZnS (Sphalerite).
Cassiterite, SnO_2.
Domeykite, Cu_3As.
Galena, PbS.
Hessite, Ag_2Te.
Niccolite, NiAs.
Siderite, $FeCO_3$ (Chalybite).
Zincite, ZnO.

Very brittle or friable.

Cerrusite, $PbCO_3$.
*Graphite, C (Plumbago).
Molybdenite, MoS_2.
*Tellurium, Te.

It is not quite possible to lay down any rule as to the best combination to use, but the following particulars are given of some of the most common:—

Zincite and tellurium, copper-pyrites or bornite.
Galena with a gold, silver, copper, or graphite (lead-pencil) point.
Galena and tellurium.
Molybdenite and silver.
Pyrites with a gold point.
Carborundum with a steel point or face.

It will be readily understood that the question of pressure depends mainly on the material in use. With molybdenite, for instance, just the slightest touch is sufficient; while with carborundum a pressure of three to four pounds is often used. When a metal point has to be used on a soft or friable material the usual practice is to have the metal in the form of a fine wire coiled up into a tiny spring, and let the end of the spring make the actual contact.

It will be very evident that the methods of arranging for contact under these varying conditions will also vary very widely. Briefly, it may be stated that the essentials to be provided always are: (1) some means of very finely adjusting the pressure, (2) provision for slightly altering the exact point of contact in order that the most sensitive spot on the crystal may be found. Consequently, the construction of a crystal detector offers plenty of scope for the amateur to exercise his skill at the bench. Most good text-books show different designs and many ingenious forms have also appeared in back numbers of the *Model Engineer.* The writer illustrates five, and gives drawings of another. The screwheads by which the final adjustment is made should be ebonite or fibre. This is a point that is frequently overlooked by inexperienced detector makers. It is almost always the case that the final adjustment is made while the crystal is in circuit. Consequently, should the adjusting screw, lever, or spring (or whatever it may be), be in metallic connection with either crystal, the operator's body may form a path for and cause partial or complete leakage of the minute currents passing. The body may also act as a condenser and so upset the tuning of the circuit. A note or two respecting the detec-

tors illustrated may be of interest. It will be noticed that in two of them provision is made for a choice of crystals by adopting what has been called the " capstan head " arrangement. The head, which is completely removable, is tapped to take four little cups, and is provided with a stem which is held in the main brass blocks by a milled-head screw. Rotation is therefore permitted, as well as a small amount of lateral movement. In fig. 25 the pressure is regulated by a fine-threaded screw acting against a phosphor-bronze spring which carries one of the capstans. Fig. 26 shows rather a different method, and is a little more difficult to construct.

FIG. 25.—A Capstan Head Detector.

One crystal is held at the end of a rod which is provided with a ball-and-socket movement, a spiral spring to give pressure, and a milled collar to alter the tension on the spring. The rod being free to move axially through the ball, can also be completely rotated. The second crystal is stationary. Fig. 27, is a very neat arrangement and provides practically every adjustment possible. Capstan heads are fitted to allow choice of crystals, rotation can be complete to either capstan head, and both can be adjusted in a vertical direction. Final pressure adjustment is made by rotating the milled-head screw at the top of the tall pillar. This pillar is really a tube and contains a spindle, the lower end of which is screwed with a $\frac{1}{2}$-mm. pitch thread. The lower end of this spindle acts on a spring-controlled first order lever, the arms of which have

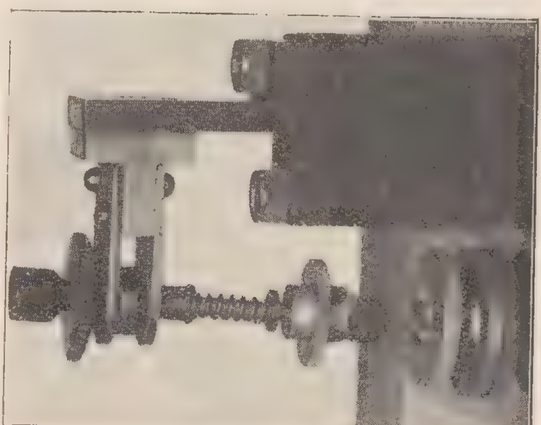


FIG. 26. Crystal Detector with Ball-and-Socket Adjustment.

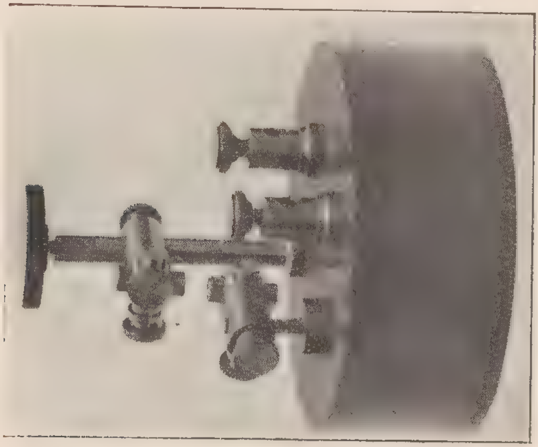


FIG. 27.—Detector with Universal Adjustment.

a ratio of 5 to 1. The short arm moves the lower capstan up and down, so that one complete revolution of the milled head gives only $\frac{1}{10}$th mm. rise or fall to the lower crystal. As the milled head is fairly large, very minute adjustment is possible. Fig. 28 is a very simple affair intended for a carborundum-steel detector. The steel blade (a piece of fairly stout clock-spring) is depressed by the milled head, and is also slotted at its fast end, so that it can be swung aside to permit removal of the crystal cup. Fig. 29 is another neat arrangement the writer constructed to order some time back, and the drawing is practically self-explanatory. The drawing

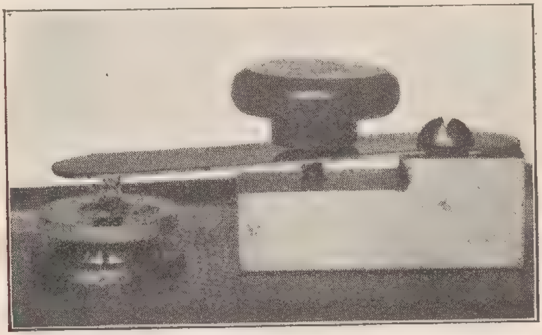


FIG. 28.—Simple Carborundum-Steel Detector.

has been done entirely from memory, and although the actual detector was scarcely as large as the measurements given, the chief features are the same. Capstan heads are used, and these are carried in brass blocks, which can travel on slide bars. The right-hand block can be moved forwards or backwards by a milled collar of ebonite, which has a centre of brass to give better wear; while that on the left is pressed forward by a slight spiral spring. The tension on the spring can be varied by the milled head on the extreme left. Every possible movement is provided; choice of crystals, rotation or elevation of crystals, and any desired pressure at contact. Damage to crystals is rendered almost impossible, as the left-hand block will recede as the one on the right is fed forward. Fig. 30 shows a very compact and ingenious type, which is generally known as the "Dennis" detector. It was very

largely used in the Signal Service, and since the war has been obtainable in fair numbers and at a very low price from those

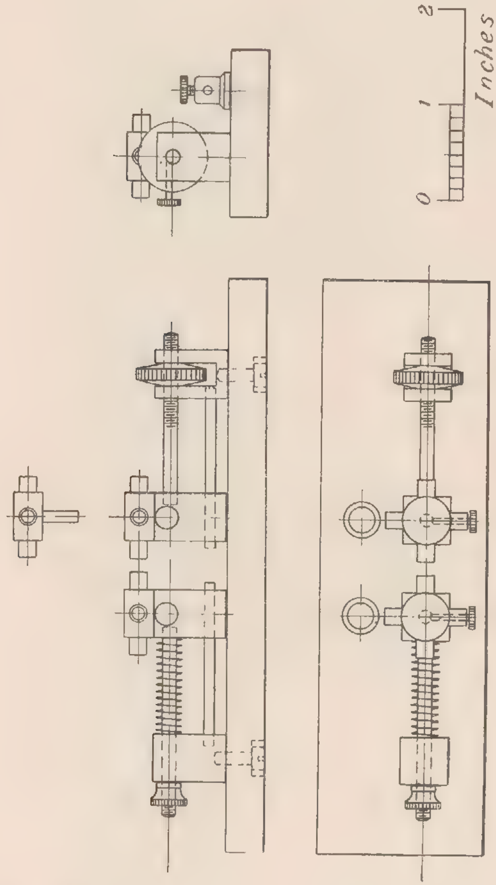


FIG. 29.—Another arrangement of Capstan Head Detector.

dealers who handled "surplus" stores. As will be seen, it consists of three separate detector units mounted on an ebonite base and covered by an ebonite cap. The pillars carrying the crystals are provided with brass pegs which project from

the circular base to which the pillars are fastened. These

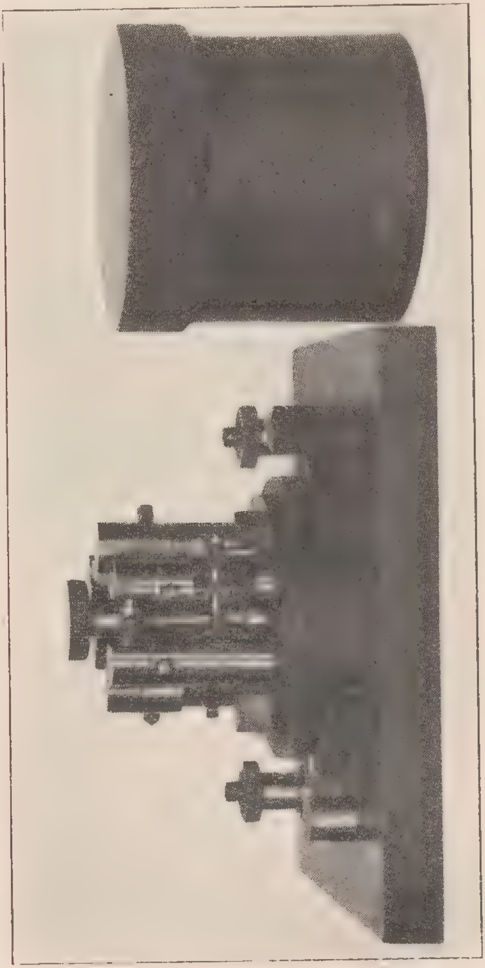


FIG. 30.—A Dennis Detector.

pegs come into contact with springs on the base proper, and the springs are connected to the terminals. When in use,

the ebonite cap is locked into position, so that by rotating it one step at a time either of the crystal combinations can be brought into service. During rotation, the exact location of either combination is brought about by the action of a spring-controlled ball housed in a small cavity in the base, the ball rising into little depressions suitably made in the under surface of the circular base. Various crystals can be used, as the tops of the pillars are removable and carry the actual crystal cups screwed into them. Lateral movement

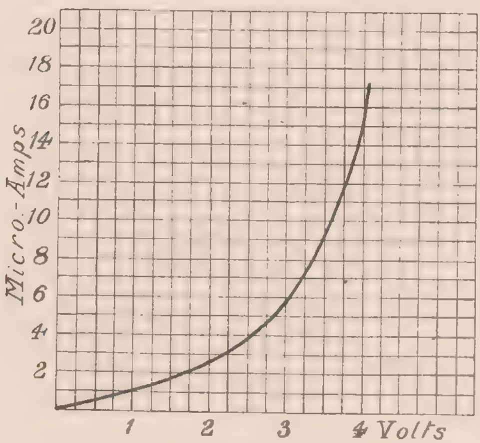


FIG. 31.—Curve showing how the Resistance of Carborundum diminishes up to a certain point.

is provided to the pillar tops by a T-slot fitting, and the actual pressure between the crystals is adjusted by an insulated screw (moved by a key), which thrusts forward against the stiff spring forming part of the right-hand pillar. The detector was originally made as a carborundum-steel combination, the steel contact taking the form of a small plate. The detector could frequently be found fitted with zincite and pyrites or tellurium crystals, however. The beginner who wants a really well-made and serviceable detector at a very low price, should not hesitate to add one of these to his stock of apparatus.

When using the carborundum-steel combination it is necessary, except for very short ranges, to apply a small voltage

to the detector, as carborundum has a critical point of sensitivity. That is to say, Ohm's law cannot be applied to it, for as the E.M.F. applied to it rises, its resistance decreases, but not in direct proportion. The decrease is rather rapid up to a certain point and then the resistance remains almost constant. Most text-books give a curve to illustrate this property, and the writer ventures to include one to emphasise the point (fig. 31). A voltage just below the maximum necessary is applied to the crystal, and it is the difference between this applied voltage *plus* the positive portion of the oscillations, and the applied voltage *minus* the negative portion that influences the telephones. When using this combination, then, it is advisable to employ a small potentiometer and a battery capable of giving about three or four volts. As the amount of current taken from the cells is extremely small, two or three dry cells of small size will prove quite suitable, and, if a switch is provided so that the cells can be cut out when the detector is not in use, will give long service. The potentiometer should have a total resistance of about 400 ohms, and is best made by winding sufficient Eureka or other resistance wire of No. 40 S.W.G. (enamelled) on a circular mandrel of about $\frac{3}{4}$ in. diam. A sliding contact should be fitted, and a tapping taken from the centre point of the winding. The diagram (fig. 32) will show how matters are arranged and also the action. Current from the battery passes through the whole of the resistance, and it will be seen that the slider taps off a varying amount as it is moved to right or left. But the most important point to notice is, that upon the slider passing the centre point, current through the detector is reversed. Hence, the correct amount of current can be obtained, and the best rectifying condition of the crystal can be brought about.

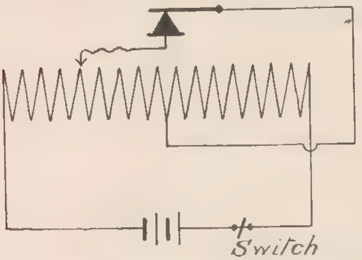


FIG. 32.—Connections of Battery and Potentiometer to Carborundum-Steel Detector.

Before leaving the discussion of detectors the writer desires to urge those who are in the beginning stages of wireless

experiments, or who are contemplating taking up this work, to begin with crystal reception. The temptation to use elaborate sets employing one or more valves is, no doubt, very great; but the writer ventures the opinion that the raw beginner who does this is courting disappointment. The wisest course for the beginner to take is to construct a set such as is described in *How to Make a Simple Wireless Receiving Set* (6d. net, post free, 7½d.), which is issued by the publishers of this work. Walking precedes running in this work, as surely as in most other. By far the best plan is to start with a simple circuit of well-established properties, and including a crystal detector. Get whatever signals happen to come along, and strive to make the reception of these as perfect as possible. Then, when familiarity with the adjustments of inductance and condenser has been attained, try for others; and when facility has been gained in correctly tuning a fair range of the more easily obtained stations, try the effect of adding a closed circuit. Next, try to amplify the signals with a valve. Painstaking experiment and careful study of the functions and behaviour of the various components in use will enable the beginner to proceed safely to more elaborate work; or perhaps critical work would be the more correct term.

CHAPTER V

TELEPHONE RECEIVERS

As was mentioned earlier, practically the whole of the reception of wireless signals is done by the use of telephone receivers. This is almost certainly the method that will be adopted by amateur workers, at any rate, and it may not be out of place if a little space is devoted to a review of the facts concerning this portion of the receiving equipment, especially as a little doubt seems, or rather seemed, to exist, on the subject, judging from the queries that are so often addressed to the wireless journals.

As most readers are no doubt aware, a telephone receiver in its simplest form consists of a permanent magnet, the poles of which are brought pretty close together, each being sur-

rounded by a coil of fine wire so wound that they will produce opposite polarity if excited by a current passing through them. In front of the poles, and as close to them as can be managed, without actual contact, is a disc of iron which is firmly held at its edge, the centre portion being free to vibrate. The iron is very thin, in order that the vibrations may be as rapid as possible and also that the small variations in the magnetic field produced by the magnet may be able to influence it (fig. 33). It is obvious that a current passing through the coils in one direction will increase the magnetic field, while one passing in the opposite direction will weaken it. These variations, however, are only momentary, so that if the applied current is continuous (or direct) and of steady

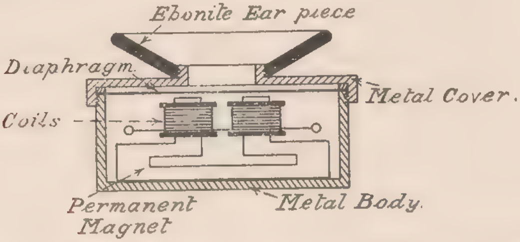


FIG. 33.--Sectional Diagram (theoretical) of Telephone Receiver.

potential a click is all that is heard as the result of the varying tension on the iron disc ; and nothing further will happen until the current ceases or its potential varies. As the current produced by spark systems of wireless is oscillatory, the rapid rise and fall above and below the mean potential will affect a telephone receiver and produce a sound (or musical note) whose pitch will be the same as the frequency of the received oscillations, provided that the telephone is, by its construction, capable of doing so. Now, in order to obtain the maximum effect it is necessary to get as much current through the telephone coils as possible ; or in other words, to vary the strength of the magnetic field as greatly as possible. If the amperage of the current is great (relatively speaking), then a few turns of wire will suffice, but as the amperage of the oscillations received in wireless working is very minute, it becomes necessary to employ a great number of turns of wire, because it is the total effect that counts. A great many

turns of wire will occupy much space unless the wire is of very small gauge, and as the available space in a telephone receiver is very limited, it follows that the wire used must be very thin. Consequently the very many turns of fine wire produce a high resistance, and so it is quite common to find telephone receivers having a resistance of 4000 ohms, or even more. As it happens, however, in the majority of cases this amount of resistance is of little consequence as most crystal detectors (and the electrolytic) have a high resistance of somewhere about the same order. The magnetic detector has a much lower resistance and so have some of the detectors employing graphite as one of the points of contact. In the early days of wireless some cases occurred where telephones were deliberately made of high resistance by winding the coils with fine resistance wire; and this was done not from any wish to give a fictitious value to the telephones, but because it was supposed that, being designed for wireless work, they must of necessity have a high resistance. The writer hopes that the old hands will forgive the labouring on this point of resistance, but feels sure it will help to put matters right for the beginners.

Telephone receivers for wireless work are expensive, and the question is often asked whether cheaper forms such as are used in ordinary telephone sets cannot be converted, that is, suitably re-wound and provided with suitable fittings for a headband? The answer is, with certain reservations, in the affirmative. The following remarks on the various essential portions of a receiver will indicate the reservations, and the amateur who intends to try such a conversion must exercise his own judgment as to whether the receiver he has in view is capable of, or worth the trouble of, converting. The magnet should be the best possible, and a compound magnet is better than a simple one. Two patterns are common. In one the magnets are of the ring type, the pole pieces being separate and screwed on. These ring magnets are generally compound, that is, there are two or three rings superimposed. In the other pattern the magnets are nearly circular, but the poles are bent inwards, and the upward pole extensions are either separate or bent at right angles from the re-entrant pieces. Theoretically it would seem that the ring type would be the better, but it appears that it is more difficult to produce good magnets of this type than the other (fig. 34). The

diaphragms of ordinary telephones are usually much too thick for wireless use, and thinner ones should be obtained. Most scientific apparatus dealers can supply, and it is hardly necessary to remark that such thin discs must be handled carefully or they will be distorted. They are then useless, and it is a hopeless task to try to remove such distortions. The telephones made by Messrs S. G. Brown are provided with an arrangement whereby the exact clearance between the diaphragm and magnet poles can be adjusted to its most sensitive point. In these excellent instruments the magnet attracts a springy steel reed, and by a screw of very fine pitch it is possible to alter the tension of the spring till the magnet

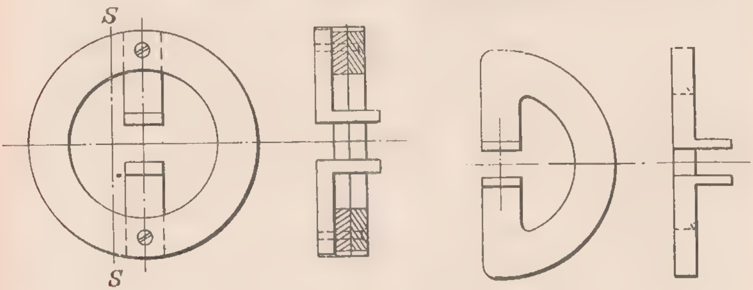


FIG. 34.—Compound Ring Type Magnet and Simple Semi-circular Magnet.

just fails to overcome it. The diaphragm is an aluminium cone, the point of which is fastened to the reed, and the edge of which is supported by a ring of tissue paper attached to an aluminium ring which is itself held by the cover of the 'phone.

Now as to the winding of the coils. One well-known maker of wireless 'phones uses No. 50-gauge enamelled wire. To anyone who has not handled such a fine wire this does not convey much. The diameter of a wire of this gauge is ·001 in., and to the beginner it would seem to be an almost impossible problem to produce a successful winding. No. 48 S.W.G. is about the limit the amateur would care to use, while if the space between the pole pieces is fairly large a wire up to No. 44 could be used—certainly not coarser. Single silk or enamel as a covering should be used, as other covering would occupy too much of the valuable space. It is advisable to rig up a

simple winding apparatus, as the actual winding is then quite comfortably performed. Cut a little block of wood sufficiently large for the coil bobbins to slip on snugly, and mount this on a stout piece of wire provided with a crank handle, and slip the wire through a stout piece of wood. Support the reel of wire on a convenient nail, and proceed with the winding, keeping a fair tension on the wire with the finger and thumb. Progress is not very fast, but it is certain. The layers can be evenly disposed, and any kinks or other untoward happenings can be noticed and checked in time. It is very necessary to see that the windings are connected up correctly, *i.e.* that they will produce a N. and S. pole respectively. A good soaking in paraffin wax on completion is an advantage, being a safeguard against damp. One maker of repute fills up the shell of the receiver with some insulating wax, leaving only the pole faces exposed.

The amount of clearance between the poles and the diaphragm should also receive attention, and should be reduced to the minimum. This clearance is usually adjusted by inserting paper washers under the edge of the diaphragm. The cover, which generally forms the clamping arrangement, should hold the edge of the diaphragm very firmly and evenly. The latter is very important, as an excessive tightness at any one spot will produce uneven strains in the diaphragm. The bodies and covers of commercially made 'phones are generally good, however, but still it is just as well to notice such points. If any uneven places are observed they may be removed by rubbing the edge of the body on some very fine emery-cloth resting on a piece of plate glass or a good surface plate. As to fittings for the headband, etc., two methods are in common use. In one a limited ball-and-socket movement is provided, while in the other the 'phone is held in a stirrup, which is itself attached to the headband by a screw or rivet at its centre. The whole arrangement is quite loose, and forms a sort of gimbal movement, giving great comfort in use by its easy adaptation to the shape of the wearer's head and ears. The adapted or re-wound receiver is likely to be somewhat heavy compared with the regulation headgear, as the specially made receiver has generally an aluminium shell and cover, and all metal parts are cut as fine as possible. It is quite common to find a complete headpiece, *i.e.* headband and pair of 'phones, weighing under one pound.

Now as to the actual resistance of the coils in the 'phones. Many beginners will like some little guidance on this point, especially if they intend to purchase their 'phones. Earlier remarks will show that, generally speaking, a fairly high resistance is unavoidable, in fact to be desired in some cases. 'Phones up to 4000 ohms each are readily obtainable, the price varying, of course, with the resistance and particular design. Personally, the writer would not trouble about going to the expense of a very high resistance. A pair in his possession are marked 1500 ohms each, and are really good. Splendid signals are obtained with them, and the writer has met other amateurs who say much the same of well-made 'phones of medium resistance. The pair in question are of French origin, and are rather larger in diameter than the usual run. They are also rather heavier, but the shape of the ebonite caps renders them quite comfortable in use.

It is very probable that these particular 'phones were very carefully made and adjusted ; the diaphragms were of just the right thickness and tension ; and so on. If the reader comes across a pair of 'phones in such good condition he is advised not to take the cover off just for curiosity, but to leave well alone. Treat the 'phones with great care also, and hang them up safely when out of use. Good magnets are very easily injured by blows. A fair range of resistance can be managed by connecting up the 'phones either in series or parallel or by using one only. Suppose each 'phone is of 2000 ohms resistance ; the pair in series will give 4000 ohms, while in parallel they will give a total of 1000 ohms. It is often possible to improve signals by trying these various combinations, as crystals vary a great deal in their behaviour.

Those amateurs who intend to do valve working will find their high-resistance 'phones of little use then, as it is very inadvisable to use such receivers with valves, the general practice being to join a pair of low-resistance 'phones in the secondary of a step-down transformer. The idea is to obviate the possibility of any passage through the 'phones of the high voltage current used in the valve. It is quite possible to use a similar transformer and low-resistance 'phones in crystals working, though results are hardly likely to be so good. Such transformers are easily made, the one point needing great care being the insulation between the primary

and secondary windings, especially at the ends where the turns of wire touch the ebonite discs. Transformers for various circuits are fitted to instruments in use in the Services, which are really wonderful pieces of work. They are extremely small and very efficient, but are machine wound and treated in a manner quite impossible for the amateur to imitate. To most amateurs the question of bulk will not matter much, and very efficient transformers can well be made at home. The one shown in the illustration is home-made (fig. 35). It is wound throughout with No. 44 S.S.C. wire, its primary having a resistance of about 4000 ohms, and its secondary about 120 ohms. The wire core is special soft iron wire of

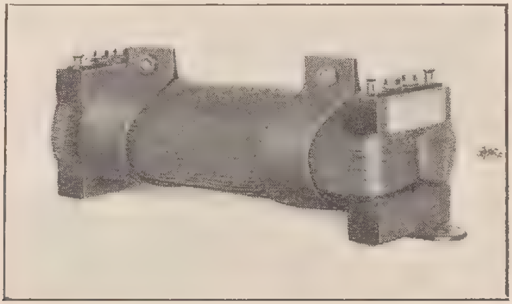


FIG. 35.—Step-down Transformer for Wireless Work.

No. 22 S.W.G., this being easily obtained in straight lengths. The end pieces are of ebonite, and insulation between core and primary and also between primary and secondary is of varnished silk. The whole transformer was finally given a prolonged soaking in paraffin wax and an outer covering of varnished linen wrapped round. The core wires, which are very much longer than the windings, are then halved at their projecting ends, and bent over on either side to form a closed magnetic circuit, and these ends which slightly overlap each other can be secured by a lashing of fine iron wire or a strip of tinplate. Transformers of this type can be wound with windings of suitable resistances to suit the worker's needs. Knowing the size of the wire, reference to wire tables will enable him to decide what length of the wire is necessary. It is not at all essential to worry about being exact to an inch,

as a few turns more or less will make very little difference. The transformer shown has a winding space of about 3½ in., and the core is about ⅜ in. diameter. The ends of the windings are taken to the tops of the ebonite ends to little terminal plates, and should be very carefully marked, so that primary and secondary can be identified. It is also as well to stick a little label on each transformer, whereon particulars of its resistance can be recorded. Some authorities on wireless advocate the use of transformers with open magnetic circuits, and certain French instruments may be met with where the cores of the transformer are left projecting some little distance. This method is said to do away with the peculiar rustling sounds heard in the telephones when using transformers.

Further information on transformers will be found in later chapters.

One little adjunct to the 'phones is a small condenser placed across the receiver terminals. It often produces very marked improvement in the quality of the signals as heard in the telephones. Its action is most probably due to the "evening-up" of the oscillating currents passing through the tuner. Small oscillations are held up or absorbed in the condenser, and so combined with the larger ones, the total effect being a sort of averaging of the current passing through the 'phones. The capacity of such a condenser need not exceed a maximum of ·002 mfd., and while a variable condenser is decidedly an acquisition, a simple block form, built up of tinfoil and sheets of good paper well waxed to the necessary capacity, will give very good results. It would be quite a good plan to construct a block condenser and divide it, arranging a little plug switch to put in varying amounts of it as required. There is no doubt that there is often a critical value to a telephone condenser, and also that this value varies with different adjustments in other parts of the circuits.

It will be found that the terminals on the earpieces of the 'phones produced by some makers are marked positive (+) and negative (−), and also that the tag ends of some telephone cords are wrapped with red or black binding. The object of this may be obscure to some beginners. When some forms of detecting apparatus are in use, there is always a very small steady current flowing through the detector, and consequently the 'phones, unless a transformer is interposed. This

is noticeably the case where a voltage-operated rectifying device, such as a carborundum-steel combination, is used. Now it has been pointed out that the magnets in a telephone receiver are permanent, and also that the coils on the poles of the magnets are so arranged that they will either aid, or tend to reverse, the polarity of the magnets according to the direction of the flow of current through the coils. Now it should be clear that if by chance the steady current passing through should be tending to reverse the polarity, then there

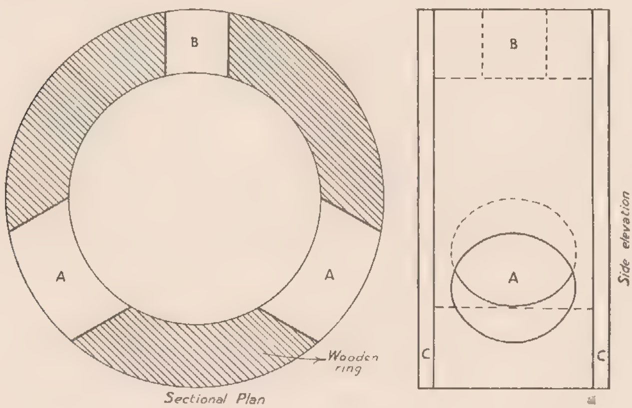


FIG. 36.—Details of a Simple Form of "Loud-speaker."

A, Apertures for telephone receiver.
B, Aperture for trumpet stem.
C, Wooden cover.

is a constant demagnetising effect going on. Hence the marking on the 'phone terminals. Consequently, it is as well to see that the two earpieces are joined up so that the positive pole of one is connected to the negative pole of the other; and also that the free positive and negative poles are connected to the positive and negative sides of the detector respectively. To help in making this a certainty the cord tags are coloured, red to positive and black to negative being the rule.

It is quite common nowadays to find amateurs using what are generally termed "loud-speakers." These are devices intended not so much to replace the usual headpiece as to enable many persons to hear the received signals without

having to provide 'phones for them all. They may roughly be divided into two classes: (1) an elaborated telephone receiver with a trumpet or horn to concentrate the sounds produced, and (2) a specially designed piece of apparatus often of rather intricate form, and sometimes requiring a separate current to operate it. Many of these loud-speakers are quite beyond the beginner's powers to construct, but good substitutes may be contrived by using a pair of earpieces mounted in a block of wood suitably shaped. The ordinary low-resistance earpieces may be used, though it is preferable to use a transformer with them, the winding of the transformer having a resistance approximately equal to the total resistance of the pair of earpieces. Some little experimenting may be necessary before the best design is attained. The angle at which the 'phones are set, the shape and size of the air-space within the block, and also the dimensions and shape of the horn are all factors upon which the magnification of the sounds depends. Fig. 36 gives a general idea of the method, and the maker must try out the exact proportions for himself. The horn is best purchased, although very satisfactory ones can be made up of paper glued together and finally varnished. Metal trumpets unless they are scientifically designed on correct acoustic lines are not, as a rule, satisfactory.

CHAPTER VI

DAMPED AND UNDAMPED WAVES

The amateur worker, who has tried to keep abreast of up-to-date developments in wireless working, will no doubt be aware of the increasing use of undamped, or continuous, waves in transmission. He will also, most probably, be aware that an ordinary receiving circuit with a crystal detector is useless for the reception of such signals, and that special means have to be employed for the purpose. The writer proposes to offer a short review of the problems presented in this form of working, addressing his remarks particularly to those amateurs who are not quite *au fait* with the subject and are desirous of experimenting a little.

In the first place it must be clearly understood what con-

stitutes the difference between damped and undamped waves. Imagine a stone dropped into the centre of a fairly large pond, and that it were possible to measure the height of the successive ripples formed on the surface of the water as they gradually spread further away from the actual point of disturbance. It will be obvious to all, that the ripples gradually decrease in height until they actually die out, or become obliterated when they reach the sides of the pond. If the measurements obtained were drawn on paper the appearance would be somewhat as shown in (fig. 37). Precisely the same kind of result would be obtained if careful measurements were taken of the amplitude of successive swings of a weight swinging at

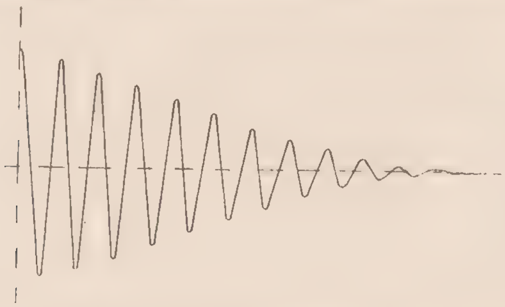


FIG. 37.—Diagram of Damped Waves.

the end of a string—a pendulum, in fact, but one entirely disconnected from any source of energy whereby its amplitude could be maintained at a fixed value by successive impulses. These two examples illustrate the form of wave or oscillation as set up by spark systems of wireless transmission. Now suppose a similar test were made, using this time the pendulum of a clock while going. It will be seen that a graphical representation of the oscillations produced in this case would be as shown in (fig. 38). This corresponds to undamped or continuous waves or oscillations.

It must not be supposed that it is owing to any defect of the crystal detector that such oscillations cannot be received by the ordinary circuits. The crystal rectifies the continuous wave well enough, but a moment's thought will show that the rectified current in this case amounts to practically a continuous current by reason of the high frequency of the

oscillations; because all we get is an extremely rapid succession of positive, or negative as the case may be, halves of waves of precisely the same amplitude and of steady frequency. If not actually continuous they are uni-directional, and that amounts to the same thing where a telephone receiver is concerned. In the spark system the damped waves follow in groups, the crystal rectifies these groups, and it is the fact that each rectified group decreases in value, that is in amplitude, and so becomes as a whole of lower frequency, that causes the telephone to respond. A glance at fig. 39 will show what is meant. At (A) the groups of oscillations are figured as received in the aerial, at (B) the rectified groups as they leave the crystal, and at (C) the re-

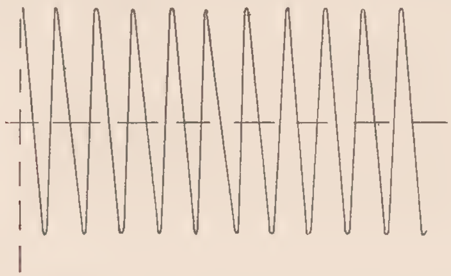


Fig. 38.—Diagram of Undamped Waves.

sulting energy as received and rendered by the telephone. Now with undamped waves these groups with decreasing amplitude and lower frequency are absent, so that all the effect produced in the telephone will be a click at the commencement and end of each signal, because the diaphragm of the telephone is simply strained or not according to the direction in which the uni-directional current is flowing through the coils of the telephone. Were the undamped waves of sufficiently low frequency the telephone diaphragm could respond in a succession of sounds corresponding to the successive half waves as they leave the crystal. Even then the frequency would have to be below 16,000 per second, as that figure is the limit of human audition. The frequency of wireless oscillations is, of course, very much greater than this figure.

The methods adopted for the reception of undamped waves

may be grouped into three: (*a*) by using the Einthoven galvanometer to produce a photographic record, (*b*) by inter-

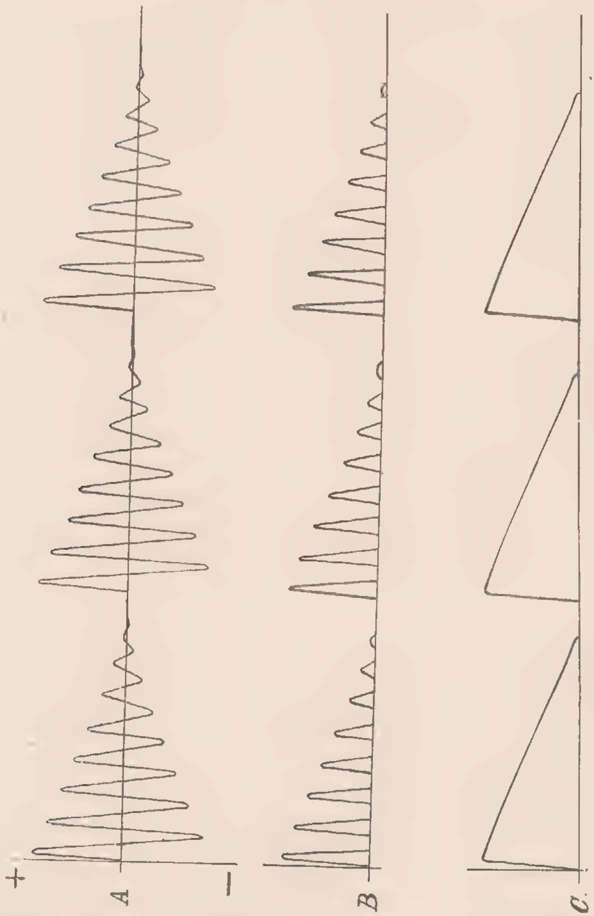


FIG. 39.—A, Diagram of Oscillations as received in the Aerial.
B, Diagram of Rectified Oscillations as they leave the Crystal.
C, Resulting Energy received by the Telephone.

rupting them by mechanical means, and (*c*) by superimposing upon them other oscillations of slightly different frequency, and so producing what are termed "beats." This is often spoken of as the "Heterodyne" system (from Greek *heteros*

=another, and *dunamis*=power) and less commonly as the "local interference system." The first method is hardly likely to come within the average amateur's scope, and as a brief description of the Einthoven galvanometer was given in a previous note, we will pass on to a consideration of the second method. The idea of breaking up the undamped waves forming a signal into groups, or otherwise modifying them to influence a telephone receiver, was first used, the writer believes, in connection with the Poulsen system. The

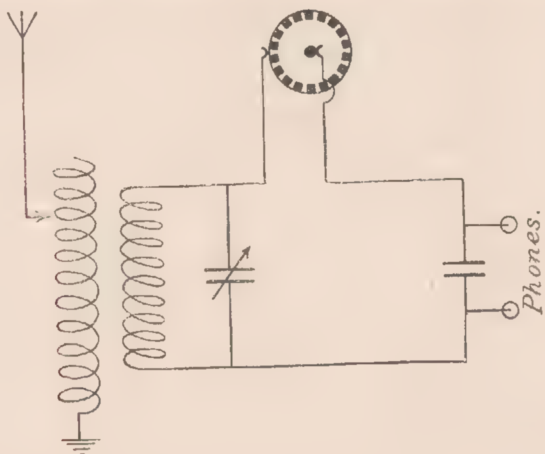


FIG. 40.—Simplified Diagram of "Tikker" Circuit (Poulsen System).

action is quite mechanical, being produced by rotating at high speed a disc, the periphery of which somewhat resembles a cogged wheel where the teeth make contact with a spring or brush and the gaps between the teeth are of some insulating material. Such an arrangement is called a "Tikker," and a diagram of the circuit in which it is used is given above. The interruptions in this system take place at a uniform rate per second, and vary between 300 and 1000 (fig. 40). As a variation of the Tikker, the "slipping contact" device has found some favour. In this a metal disc is rotated at high speed. A light spring presses on its edge and another presses against its face just a short distance from the edge. This latter spring, owing to the high speed of the disc, makes an

imperfect contact, alternately slipping and then gripping again. In America an arrangement known as a " chopper " is largely used, and this would seem to be as simple as any, provided a supply of alternating current is available. Briefly, it consists in adding to a crystal circuit a lightly adjusted relay, the armature of this being set in rapid motion by joining the coils in series with the alternating mains through a lamp or other fairly high resistance. The diagram (fig. 41) will explain. It is necessary to use, also, a fixed condenser of

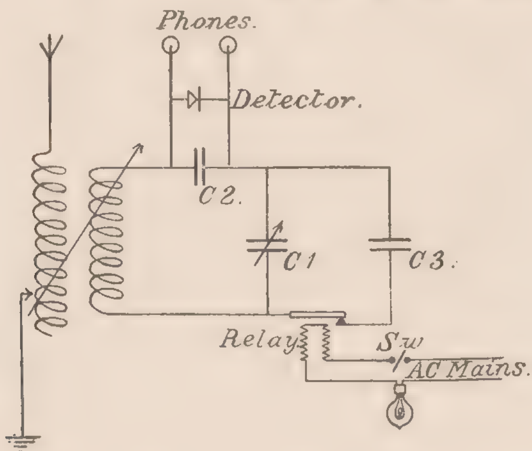


FIG. 41.—" Chopper " Circuit.

fairly high capacity—somewhere about ·15 mfd.—to get the best results. The crystal circuit is constantly thrown in and out of balance by the charges in the large condenser C_3; and as the frequency of the alternating current is so very much lower than that of the oscillatory current passing the crystal the result is a series of pulsations through the telephone. The nature of these pulses will be more apparent when the subject of " beat " reception is discussed.

The Goldschmidt " Tone-wheel " is an exceedingly ingenious arrangement, whereby undamped oscillations of radio-frequency are converted to those of audio-frequency. It overcomes a defect inherent to the Tikker system, and can be so adjusted as to give a perfectly clear musical note in the

receivers, whereas in the latter the note is rarely of regular pitch. Its action is briefly as follows :—A mechanically operated interrupter is made to break either the positive or negative half of each oscillation. Were these interruptions made exactly at the peak of each half wave the only effect in the telephones would be clicks at the commencement and ending of the signal owing to the high frequency. But the tone wheel is made to interrupt just a little late, so that varying amounts of positive and negative current flow through the telephones, the proportions of each being reversed as the zero line is passed, so that it is really the rising and falling differences that influence the receivers. As the whole process is carried out at a perfectly uniform rate, the radio-frequency becomes converted to audio-frequency. A little study of the diagram

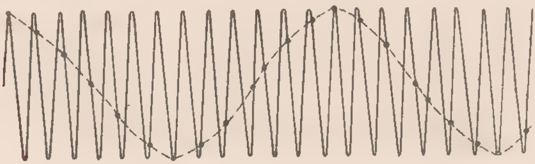


FIG. 42.—Full line : Diagram of Received Oscillations. Dots : Point of Interruption. Broken line : Resultant in Telephone.

will make the action clear (fig. 42). Full lines = received oscillations. Dots = point of interruption. Broken line = resultant in telephone.

In the third method an oscillating current is generated at the receiver and made to operate the receiver circuit. In the earlier forms a musical arc was employed to generate the local oscillations, and in the receiver circuit a crystal detector was employed. In the modern system the oscillations are generated by a vacuum valve, and two alternative methods are available. The valve may be used simply as a generator and the actual detection carried out by a crystal. The valve may also act as a generator and detector at the same time. In either case the oscillations generated by the valve are of different frequency to those it is desired to detect. The result is the production in the circuits of what are termed " beats," and it is these rapidly recurring beats that influence the 'phones. Fig. 43 will show the production of beats dia-

grammatically. Imagine a tall man walking with a short one, and the two keeping constantly abreast of each other. The tall man will most probably take longer steps than the shorter; consequently the shorter man will make more steps per minute than his companion. A very elementary know-

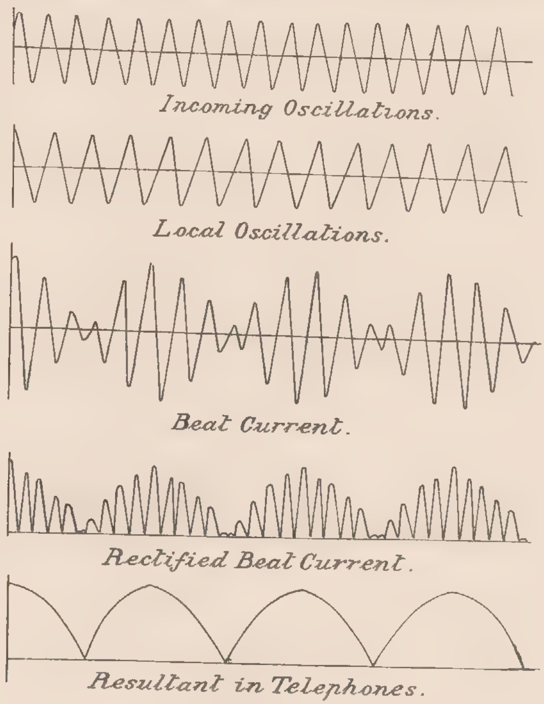


FIG. 43.

ledge of mathematics will make it clear that ever so often their footsteps will coincide, and they will then gradually go out of step again. This will be succeeded by a gradual coming into step again, and so on. The exact moments of "in-step" will represent the beats, and it is important to remember that these beats are occurring at a uniform rate relative to the two movements producing them. Or sit quietly in a room where two pendulum clocks are going.

Should the pendulums be of different lengths the gradual approach to and departure from successive beats will be very clearly heard. Two watches, the balance wheels of which oscillate at different frequencies, will provide another illustration. It is quite possible, indeed most likely, that the amplitude of the incoming oscillations and that of the locally generated oscillations will differ. This will make no difference in the production of beats, as it is the difference in frequency that is essential.

It is presumed that the great majority of amateur workers who are desirous of attempting the reception of undamped waves, or as they are generally termed nowadays "C.W.," will contemplate the use of a valve; and one of the purposes of this review of the subject is to lead them to observe that such a method involves putting energy into the aerial.

It was for this reason that when permission to receive wireless signals was again granted upon the coming of peace that diagrams of circuits involving the use of valves had to be produced with the application for permission. These circuits were undoubtedly very carefully scrutinised. In most cases, too, the number of valves included in the circuit was definitely specified in the permission when granted. Fortunately, however, this condition is not now in force, and this is no doubt largely due to the fact that the great majority of amateurs did endeavour to keep such radiated energy within the closest possible limits. The matter is dealt with more fully in Chapter IX.

It is to be noted that the various methods employed for C.W. reception will all permit of the reception of damped oscillations, though where mechanical methods are employed the results are not nearly so pleasing as with ordinary crystal reception.

The Marconi Co. have introduced, with much success, a system of receiving C.W. by modifying the system of "balanced crystal working," also largely used by the same company. A separate circuit is coupled to the receiver circuit and is kept oscillating by a buzzer. The crystals, which are so adjusted that they would normally receive only strong signals, are periodically affected by this buzzer circuit, with the result that they permit rushes of current to pass from the main condenser, which is kept constantly charged by the incoming C.W. The frequency of the buzzer circuit is usually a sub-multiple of that of the incoming energy, so that by this

means oscillations of audio-frequency are passed to the telephones. Good results are obtained in long-distance working by this method.

It may occur to some to inquire why the C.W. system of transmission is finding favour so increasingly. The advantages in employing this system are briefly as follows:—

1. Higher speed of signalling. With spark systems the periods of inactivity between the groups of signals are of comparatively long duration. In C.W. this is not so; hence it will be possible to produce automatic transmission and reception at high speeds.

2. Wireless telephony is only possible by using this system, as the sound of the spark would always be present with a damped system.

3. Greater control owing to the perfect syntonisation possible, and consequently less interference between stations.

4. Simpler and less costly apparatus is required for transmission, and more reliable apparatus is possible for reception.

5. It will be possible to employ greater power in transmission, as with spark systems it would seem that the limit of power has been practically reached.

6. C.W. lends itself far better than spark systems to directive effects using special aerials.

It is, perhaps, hardly necessary to remark that the illustrations of the various wave forms are not intended in the slightest degree to be to scale, but are purely explanatory diagrams.

CHAPTER VII

SOME TUNER CIRCUITS

It is proposed to give in this chapter some details of the circuits the beginner may employ, so that after making a decision as to the particular set he fancies, or feels capable of putting together, he may set about its construction with a better idea of what he will want in the way of inductances, etc. A complete specification is not given here, as full instructions for making a beginner's outfit are given in *How to Make a Simple Wireless Receiving Set* (6d. net, post free 7½d.,

Percival Marshall & Co.). But the author recognises that different needs are felt by different inquirers. The objectives of wireless enthusiasts vary so widely, their means or the material at their disposal may also vary greatly, while their constructive ability and theoretical knowledge are also very big factors which have to be kept in view. It would, therefore, be a remote possibility that the complete specification of any one set would give equal satisfaction to all. Instead, and in order to make this chapter as useful as possible to all, it is intended to offer diagrams of a fair number of reliable circuits, together with some hints on each, leaving it to the individual concerned to select what he considers most suitable to his requirements or capabilities. It must be remembered that the methods of joining up the various components comprising a receiving set are, practically speaking, illimitable, and provided the fundamental principles are observed, results of some sort can be obtained. The writer does not believe there is any "best" arrangement, for a great deal depends upon the operator, to say nothing of the maker. Some sets, too, have little idiosyncrasies of their own, and the most trifling adjustment or alteration to some part may make a most marked difference in the signals received.

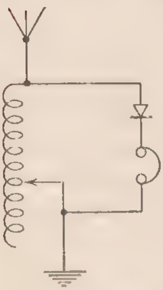


FIG. 44.—Simple Tuned Circuit.

The diagrams shown are of sets of varying elaboration, starting from the most simple; and a few remarks on each will serve to indicate any particular feature it possesses. The writer presumes that all those interested are familiar with the now more or less standard method of indicating condensers, inductances, coupling, etc.

Fig. 44 is a simple tuned circuit. Here an inductance of about 4 in. diam. and 8 in. in length, wound full with No. 22 or 24 wire, and provided with a sliding contact, might be used. The variable condenser could be omitted if the set is to be used on very short ranges, while any crystal detector will serve. The coupling is fixed and the wave-length is varied by including more or less of the inductance in the aerial. Close tuning is not possible.

And, speaking of coupling, makes it as well, perhaps, to

explain the meaning and importance of this feature in wireless circuits. By coupling is meant the placing of inductances with regard to each other in order that electro-magnetic induction can take place between them. The primary and secondary windings of a spark coil, for instance, are coupled. It will be noticed that it is not by any means necessary for the windings of the inductances to be in metallic continuity; as long as one is within the magnetic field of the other they are coupled. If the coupling is such that something approaching the maximum effect may be obtained, the inductances are said to be "closely" or "tightly" coupled, while if the effect is relatively small, then the term "loose" coupled is applied. Two coupled circuits, therefore, form a transformer. Now if the coupling is variable, there will probably be one position in which the most *effective* results will be obtained, and this enables the operator to obtain what is termed "fine" tuning. In other words, he can select very critically signals on some particular wave-length, though there may be others of different wave-length also coming in on his tuner at the same time. And, generally, the looser the coupling is, the greater is the selectivity. It is often the case that the energy present in *one* inductance is distributed through two circuits, so that these two circuits are coupled. In this case the term "direct" coupling is applied, and the whole device forms an auto-transformer.

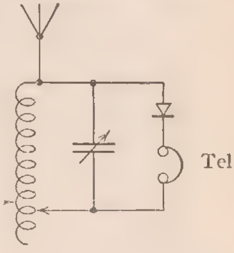


FIG. 45. Simple Tuned Circuit with Variable Coupling.

Fig. 45 is an advance on the last set, as coupling is variable to some extent. The same components would serve, but the inductance should be provided with *two* sliding contacts. This form of receiving set is very useful if work is to be carried on at one wave-length only. Adjustments are made till the best signals are obtained and the exact points of adjustment noted. This circuit is also most useful where little interference is likely to be met with.

Fig. 46 shows a tuner with loose coupling. The inductance already given will serve for the aerial circuit, while a smaller one of about 3 in. diam. by 6 in. in length, and wound with

No. 24 or 26 wire, could be arranged to slide within it. The adjustments from this closed circuit inductance are best made by bringing out tappings from various points on it to a multipoint switch. Neither condenser need be very large, while that in the closed circuit can be about half the capacity of that in the aerial circuit. A very small fixed condenser across the telephone terminals may be added with advan-

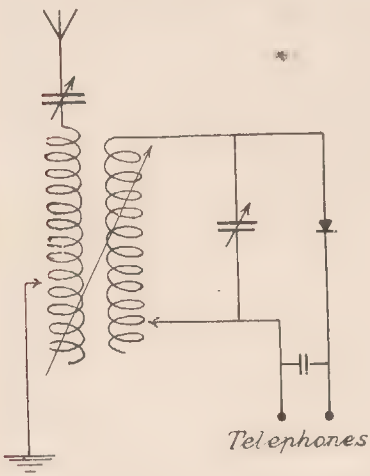


FIG. 46.—Tuner with Loose Coupling.

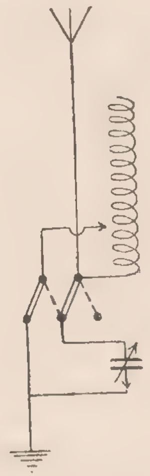


FIG. 47.—Aerial Circuit Condenser in Series or Parallel with the Inductance.

tage. Such a condenser was described and its use explained in Chapter V.

Fig. 47 indicates a useful variation of the aerial circuit. By means of a two-way switch the aerial circuit condenser can be placed either in series or parallel with the inductance. This alteration often enables much improvement to be obtained with signals which are sometimes difficult to obtain with satisfaction.

Fig. 48 shows how a tuner with loose coupling can be provided with a "stand-by" and "tune" arrangement. This is done by using a double-throw double-pole switch connected as shown. With the switch at stand-by position

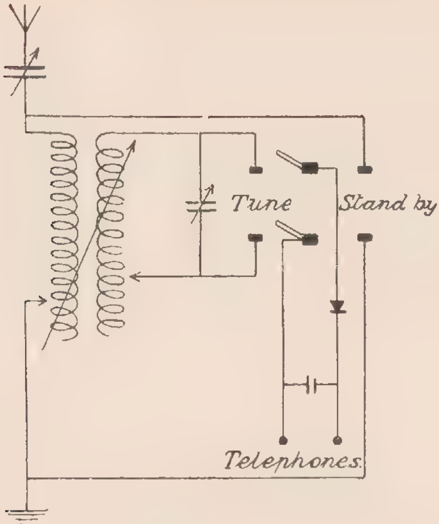


FIG. 48.—Loose-coupled Tuner with a "Stand-by."

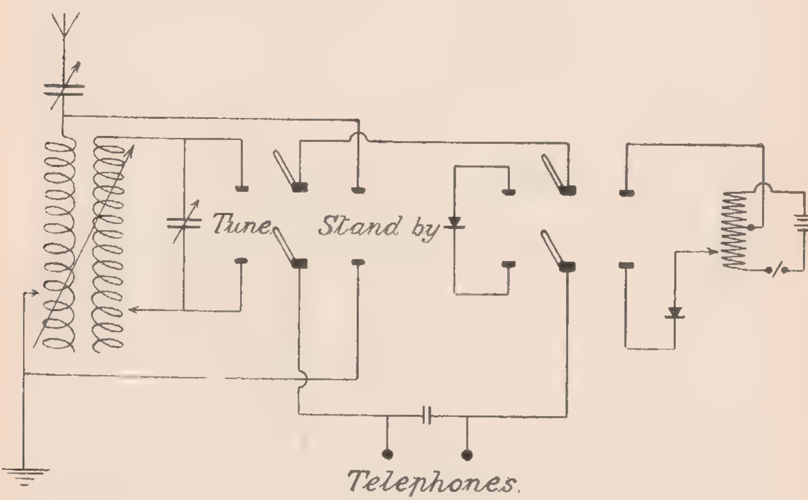


FIG. 49.—An Elaboration of Circuit shown in fig. 48 with Alternative Detectors.

signals are received, and the switch is then thrown over to tune position and final selection made.

Fig. 49 gives a further elaboration where, in addition to a switch for stand-by and tune positions, a choice of detector is permitted. A second double-throw double-pole switch is fitted, and the diagram shows the wiring for a simple crystal detector, and one such as the carborundum-steel where a battery and potentiometer are necessary. It should be noted that where a stand-by and tune switch is provided, it is of considerable advantage to provide, also, a means whereby the

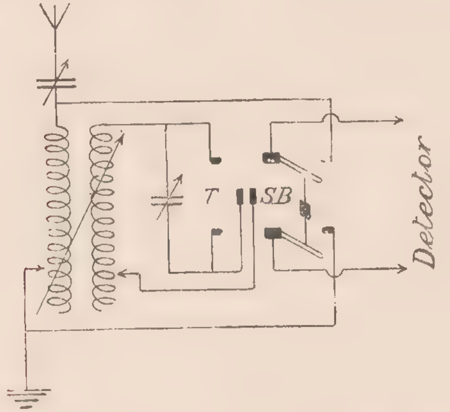


Fig. 50.—Method of Interrupting Closed Circuit.

closed circuit may be broken when using the stand-by position. Otherwise the closed circuit, being still complete, will continue to act as one side of a transformer, and the oscillations produced in it will exercise a very considerable choking effect on the aerial circuit. An arrangement whereby this interruption of the closed circuit can be brought about is shown in fig. 50. It consists of providing two small spring blades which can be joined by a little roller supported on an insulating bar between the two blades of the double-throw switch, and connected up as shown.

A very elaborate but extremely ingenious arrangement for using large inductances to work over a long range of wavelengths is given in fig. 51. It is adapted from a tuner largely

used in the Signal Service, but requires very careful construction. Briefly, each inductance, aerial and closed circuit,

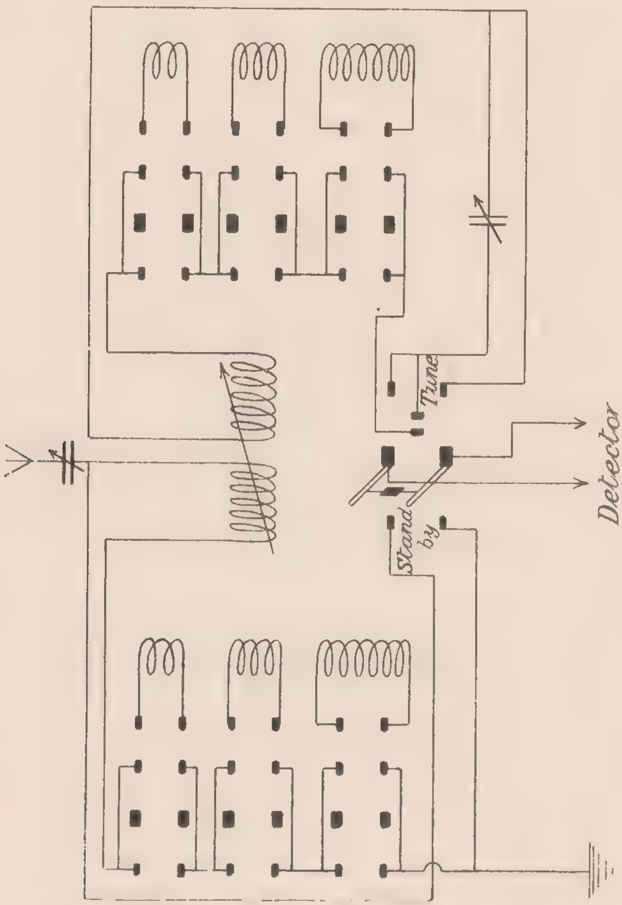


FIG. 51.—Arrangement for using large Inductances to work over a long range of Wave-lengths.

is divided into four; two relatively small, the third considerably larger, and the fourth as large, or even a little larger, than the first two together. The second, third, and fourth portions of the inductance are each provided with a switch,

and fig. 52 will give an idea of its construction. A piece of ebonite or fibre shaped like an L is pivoted at its angle. On its faces are metal surfaces which make contact with spring blades. The two metal surfaces on the long arm are insulated from each other, while those on the short arm are connected through the substance of the switch arm. Reference to fig. 36 will show how matters are arranged. The short arm being down, that particular inductance is short-circuited, while if the long arm is down the inductance is in circuit, being joined in series. This means that it is possible to introduce eight different inductance values, while at the same time the dead-end effect of an inductance, not included in the circuit, is entirely obviated. Coupling is varied by using the first portion of the inductance of each circuit and bringing these two into relation with each other. It will be noticed that the closed circuit may be opened or short-circuited by the throw-over switch. The inductances (or rather portions) 2, 3, and 4 could be of the "basket" type, if space is a consideration. For those amateurs who desire quite a simple, but reliable, circuit for the reception of telephony, either of those shown in figs. 46, 48, and 49 should serve very well.

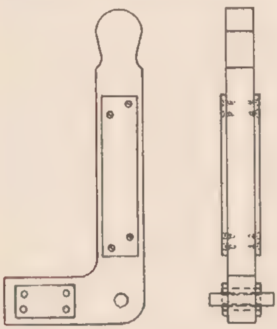


Fig. 52.—Form of Switch for inserting Inductances.

Having now considered some of the simpler forms of receiving circuits, where crystal detectors are employed, we are brought to the point where many beginners find themselves at a standstill. They are desirous of fitting up a receiving set and probably have quite a fair knowledge of the make-up of a tuner, and the functions of its components. But the difficulty to them is the size or proportion of these components, *i.e.* the dimensions of the inductances and the capacity of the condensers. A study of the queries, and their answers, appearing week by week in the *Model Engineer*, for instance, will prove the truth of this statement. Now, with a little consideration, any amateur should be able to supply himself with sufficient data to give him a good working basis on which he may proceed with confidence in the construction of his set.

The results of his calculations will almost certainly not be exact enough to warrant a precise prediction of the behaviour of the completed set, and subsequent experience of wireless work will show him how difficult such a problem would be. He should be able, however, if he aims at working on a definite range of wave-lengths, to produce a set which will fulfil that aim with no other adjustments than those normally provided in such a set. Let us enumerate the essential requirements. We shall need an aerial, inductance and capacity, a detector to render the received energy usable, and a pair of 'phones to produce sounds from that energy. The two latter items we can dismiss from the present discussion. The aerial itself will provide some inductance and capacity; and here it is extremely difficult to help the beginner who sends along a query. Unless one can actually measure an aerial, and note its form and disposition, it is almost impossible to make anything like a definite statement. As was pointed out in Chapter I., aerials may be of very varied form and size, and beyond this, the surroundings of the aerial often play an important part in the actual results obtained from the receiving set connected to it. Nearly all calculations are based on "wave-length," and wave-length is almost entirely dependent on the inductance and capacity in the circuit. Now as an aerial possesses both these quantities, it follows that any particular aerial must have a certain "natural" wave-length of its own. The beginner need not worry a great deal about the precise wave-length of his aerial, but take it as an established fact that for an average aerial the wave-length will be 4 to $4\frac{1}{2}$ times the length of the aerial, plus the lead-in. Now as the amateur is restricted to a maximum length of 100 ft. for his aerial (plus lead-in), it is easy to see that 100 ft. $\times 4\frac{1}{2} = 450$ ft., or 137 metres; and further, he must take it as a fact that the capacity of such an average aerial will be somewhere about 0·0001 mfd. This means that the aerial will be at its maximum efficiency (*i.e.* without any inductance and capacity other than its own) when responding to signals at that wave-length. For anything greater it becomes necessary to load up the aerial with further inductance and capacity, this being provided in the receiver circuits connected to it.

There are two common formulæ for determining the wave-length of a circuit, and these reduced to their very simplest form may be used by the beginner to give data from which,

by formulæ already given, the particulars of inductances and condensers may be obtained :—

$$\lambda = 1885\sqrt{L \times K} \quad . \quad . \quad . \quad \text{(i.)}$$

where λ=wave-length in metres ;
L=inductance in mhs. ;
K=capacity in mfds.

Or,

$$\lambda = 60\sqrt{L \times K} \quad . \quad . \quad . \quad \text{(ii.)}$$

where λ=wave-length in metres ;
L=inductance in cms. ;
K=capacity in mfds.

It should be possible for the reader now to follow clearly the procedure necessary in order to set about designing a receiving circuit. First, the range of wave-lengths over which it is desired to work must be settled. Then, taking into consideration the natural wave-length of the aerial, the rest must be made up in the receiver circuit. As the capacity of the condenser used should not be unduly great, and again, as this capacity is generally known, or easily determined, the factor K in the above formulæ is available. Substituting this value of K and resolving the equation will give the amount of inductance necessary. Knowing this value, the actual dimensions, gauge, and turns of wire are determined by the formulæ given in Chapter II.

As an example, suppose it is desired to receive signals up to 3000 metres wave-length, and a condenser of 0·001 mfd. capacity is available, what amount of inductance must be supplied ?

$$\lambda = 60\sqrt{L \times K}$$

$$3000 = 60\sqrt{L \times \cdot 01}$$

$$9{,}000{,}000 = 3600 \times L \times \cdot 01$$

$$\therefore \quad L = \frac{9{,}000{,}000}{36}$$

$$= 250{,}000 \text{ cms.}$$

This result provides the basis for the next set of calculations as explained above.

CHAPTER VIII

VALVES AND VALVE WORKINGS

In view of the increasing use of the vacuum valve in wireless telegraphy and the great progress made during the last four or five years, it is proposed to devote some little space to the valve as used in receiving apparatus. Some common type of valves will be described and then a few circuits given, which it is hoped will be of interest to the amateur wireless worker. As a vast amount of experimental work was carried on during the war, it is quite possible that many beginners in wireless work may not have a clear understanding of the why and wherefore of the action of a valve, and it is the writer's intention to give a short explanation of the matter in as simple language as possible, so that the amateur who aims at including a valve circuit in his equipment later on shall have a fair understanding of the essentials of such a circuit, and may be able to extend his knowledge of the subject by actual experiment in conjunction with his reading from a suitable text-book.

The valves as now produced and used are the result of much patient investigation and experiment, during which difficulties of much magnitude have been gradually overcome. To the uninformed observer there would seem to be little more difficulty in the construction of a valve than in that of an ordinary incandescent electric lamp. The addition of two metal conductors to the present-day lamp, with its metal filament, high vacuum and well-shaped bulb, certainly does not convey any idea of the difficulties which arose and had to be solved. Briefly, the great trouble was the production of as good a vacuum as possible. Early experimenters had stated that the presence of air, or other gas, in a very attenuated form was essential to a vacuum valve. Later investigations proved this to be a mistaken view; that is to say, where valves of great efficiency were concerned. Now most metals contain minute quantities of gases absorbed in them, and it was the elimination of these traces that proved the difficulty. To the reader who is at all hazy on the subject of what a high vacuum means, the following figures may be of interest: Air, at normal pressure, will support a column of mercury 760 mm. high (approx.). The pressure of air (or other gas)

in a vessel which has been more or less exhausted is expressed as the amount of mercury it will support. In a well-made incandescent electric-light bulb the vacuum often approaches the order of 0·000001 mm. (!), and pressures much less than this are essential in some forms of vacuum valves. Conditions prevailing within the valve are very different to those in the incandescent bulb. Then, again, it is not possible to produce valves of satisfactory quality in batches; and as the great degree of exhaustion necessary takes considerable time, and in its final stage much care, it is hardly likely that valves will be cheap items in a wireless set. The writer remembers very well hearing the opinion expressed, some time ago, that valves at three or four shillings each would presently be available for the amateur; but this is very doubtful.

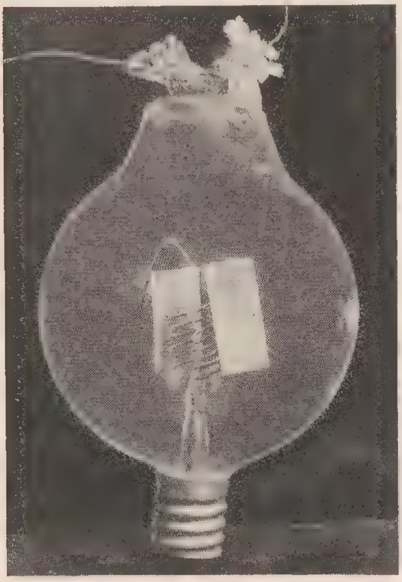


FIG. 53.—A B.T.H. "Audion" Valve.

Valves may be classified, broadly, into the groups "hard" and "soft." These terms indicate the degree of vacuum to which the valves have been subjected; the higher the vacuum the harder the valve. The significance of the two types will be given later.

With these preliminary remarks we will pass to a consideration of some types of valves. Fig. 53 shows what is called an "Audion." It is made by the B.T.H. Co., and provided with a small Edison screw cap, this forming the leads to the filament. This latter is looped and its working voltage is 4. The grid takes the form of gridiron-shaped wires on each side of the filament, the plates being of nickel. The grid and plate leads are sealed through the upper part of the bulb. The

valve is of the "soft" variety, and its plate voltage is about 40 to 50. The valve is rather fragile and the filament current requires careful adjustment.

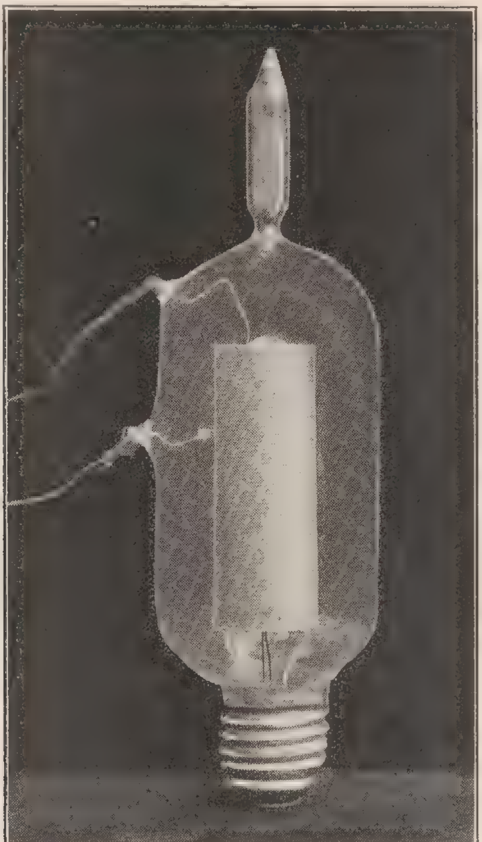


FIG. 54.—A Marconi "Round" Valve.

Fig. 54 shows a valve as used by the Marconi Co., and is often referred to as the "Round" valve. It is rather a large valve and is provided with an oxide-coated filament.

The grid is of wire gauze and the plate is cylindrical. Connection to the filament is made through the screw cap, which is the standard $\frac{7}{8}$ in., while leads from the grid and plate are sealed to loops in the walls of the bulb. This valve is also of the "soft" variety, the H.T. voltage ranging from 40 to 70. This valve is fitted with an arrangement whereby the

FIG. 55.—A Marconi "Q" Valve.

FIG. 56.—A "French" or "R" Valve.

vacuum may be lowered slightly. An extension at the top of the bulb contains a small amount of asbestos fibre.

This substance has the property of releasing a small quantity of the air absorbed in it when its temperature is raised. The extension is surrounded with a small coil of resistance wire, and upon current being passed through this coil the heat generated releases the air necessary. The writer considers that this valve should always be used with its cap uppermost, as the filament, being rather long, shows a tendency to sag considerably when heated. Fig. 55 is what may be termed

a miniature round valve. It is also largely used by the Marconi Co., and designated by them the "Q" valve. The filament runs along the long axis of the valve and connection to it is made by small conical caps at the ends of the tubular bulb. The filament does not extend the whole length of the bulb, and at one end the interior portion of the lead is in the form of a spring, so that the sagging of the filament is taken up. The grid is of gauze, and the plate is cylindrical; leads from these being taken to two conical caps on the sides of the tube. The filament voltage is 6, and the usual H.T. voltage is from 35 to 70. A valve almost identical in appearance to the "Q," and by the same makers, is the "V.24." It is, however, somewhat different in internal arrangement and is specially suitable for amplification. The "French" valve shown at fig. 56 seems to be the most popular at the present time. The filament voltage is 4, although when used for transmitting this may, with suitable arrangements, be raised to 6. The grid is of spirally-wound wire and the plate is cylindrical. Connections from the filament, grid, and plate are brought to four pins fitted to the cap, and these pins are not evenly spaced, so that it is not possible to insert the valve into its holder in a wrong position. This ensures that grid and plate are correctly joined up, and also prevents burning-out the filament by getting it joined up to the

Fig. 57.—"R.4.B" Valve (M.-O. Co.).

H.T. battery. The valve is of the "hard" variety, a common H.T. voltage being 150. The shape of the bulb varies according to the maker. Fig. 57 shows the "R.4.B" valve as made by the Marconi-Osram Co., and fig. 58 gives its characteristic curve. This valve is especially good as a detector. Fig. 59 illustrates quite a new valve by the same makers, its designation being "L.T.1." It should become very popular with amateurs, as it is designed to work at a voltage of 1·8 on its

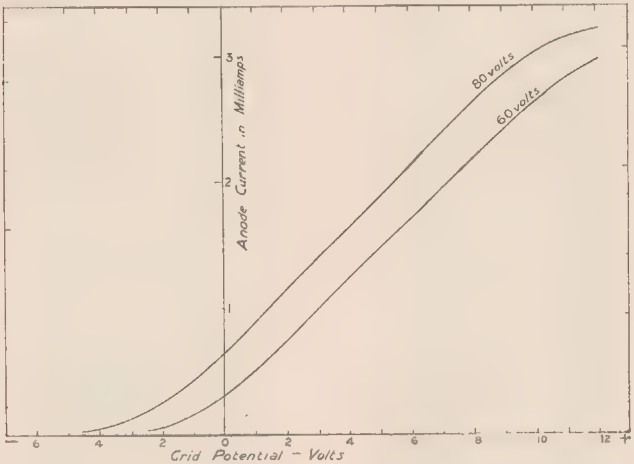


FIG. 58.—Curve of "R.4.B."

filament, the current at that voltage being only 0·4 amp. This means that a 2-volt accumulator only is necessary in place of the usual 4- or 6-volt. From its characteristic curve (fig. 60) it will be seen to give results approximately the same as the ordinary "R" type. Another valve of exactly similar pattern, but designated "L.T.3," works at the same voltage but requires a current of only 0·11 amp. Both these valves require an anode voltage of from 35 to 50. In fig. 61 is shown a valve that is rising in popularity at the present time. It is the Mullard Co.'s. "Ora," and its great feature is the small amounts of current taken by the filament and anode respectively. A study of its characteristic curve (fig. 62) will show its behaviour. It is equally suitable for either high- or low-frequency ampli-

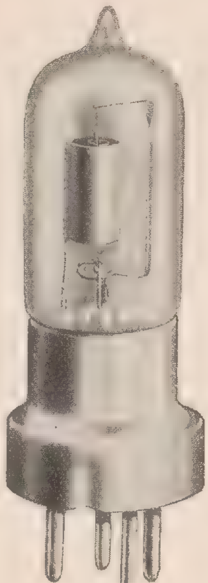


FIG. 59.—" L.T.1." Valve (M.-O. Co.).

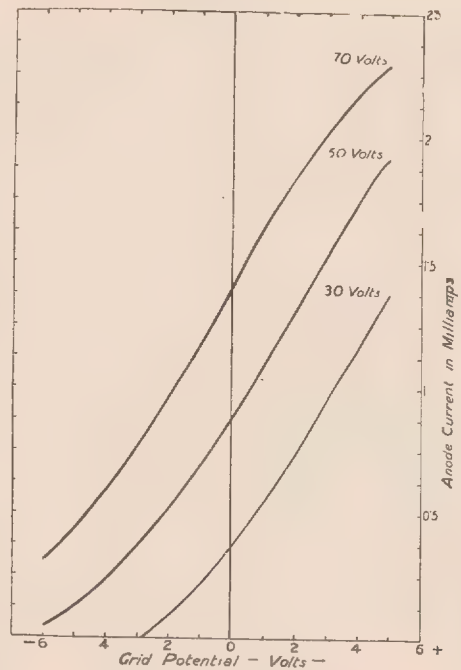


FIG. 60.—Curve of L.T.1.

FIG. 61.—" Ora " Valve (Mullard).

fication, while it is also an excellent detector when used with a leaky condenser in the grid circuit. Another point of interest is the small size of its bulb. It is just the valve to use in apparatus where space is limited. Fig. 63 shows quite a new departure from the usual form of valve. It is the "R.M.R. Cossor" "Mushroom" valve—so named because of the peculiar shape of the grid and anode. Very gratifying results have been obtained with this valve, which is a little softer than the usual types. The makers recommend that the grid

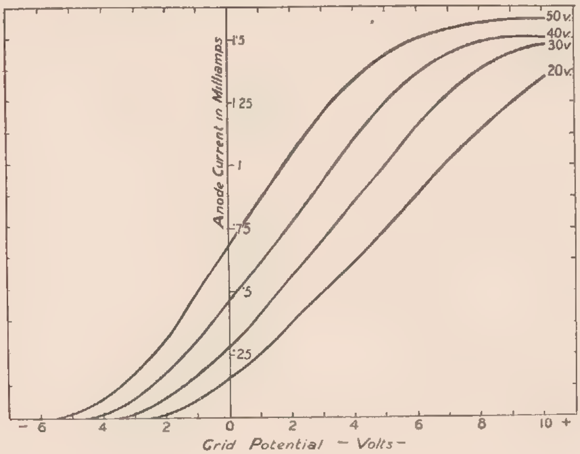


FIG. 62.—Curve of "Ora."

potential be controlled by a potentiometer. With this device, and a plate voltage of 30, very silent working is obtained. Fig. 64 shows the characteristic curve of this valve.

Other valves may be met with, and doubtless other forms will yet make their appearance. Those employed for transmission are generally larger, and are capable of dealing with much larger currents and of much higher voltage across the filament and plate. The amateur is unlikely, however, to have much to do with these, for a time, at any rate.

Now, a little as to the working of a valve. The glowing filament of a valve (or incandescent electric lamp—for a valve is essentially the same as far as its filament is concerned) tends to emit electrons. These are minute negative charges

of electricity, and are repelled by other negative charges and attracted by positive charges. The filament emits electrons to the extent to which it is heated, so that an arrangement as shown in fig. 65 will permit of the control of electron emission. With such an arrangement electrons are emitted and form a negative charge on the inside of the bulb. This charge repels further electrons, and emission may then cease. If a metal conductor be introduced into the bulb, and fixed at a short distance from the filament, it can be made to alter very considerably the state of affairs within the bulb. Should the plate be kept at a positive potential with respect to the filament then it will attract the negative electrons, and a current of electricity will flow from the filament to the plate. If, however, the plate be kept at a negative potential, that is, at a lower voltage with respect to the filament, then

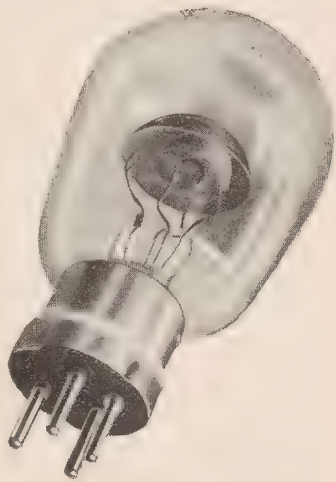


FIG. 63.—" Mushroom " Valve (R.M. Radio).

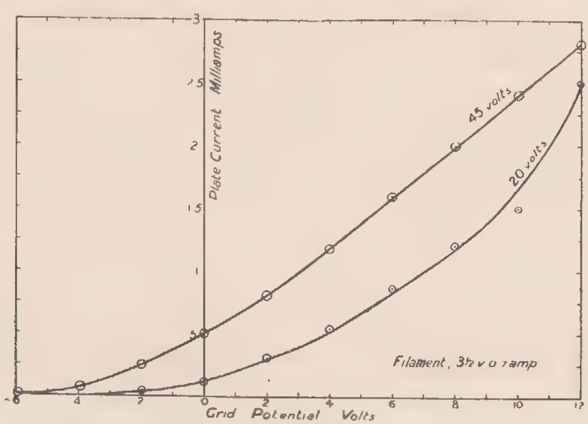


FIG. 64.—Curve of "Mushroom."

it will repel the electron discharge; with the result that a dense field of electrons will surround the filament and most effectually prevent any further discharge. The difference of potential may be kept up by a battery of cells suitably connected, and the flow of current from it through the bulb to the plate will be constant, provided: (1) the temperature of the filament is constant, (2) the potential is steady, and (3) the vacuum of the valve does not vary. The magnitude of the electron flow will increase as the temperature of the filament increases, and also as the positive potential on the plate rises. It will be understood that, as the positive potential on the plate rises in respect to the filament, there will come a point where all, or practically all, the electrons discharged from the filament will pass to it. This is known as the "saturation" point. Following this, it will be seen that for any particular value of current used for heating the filament there must be a corresponding potential on the plate, in order to produce saturation. A further rise in potential will produce no effect. Consequently, if saturation is not obtained, any fluctuations in the plate potential must produce corresponding fluctuations in the stream of electrons emitted. If, now, a circuit be made up as shown in fig. 66, where the potential of the plate can be varied by means of a potentiometer slider, rushes of current can be made to pass from filament to plate as desired. The same effect can be produced by using suitable connections to the battery used in heating (or lighting) the filament (fig. 67). It is necessary to let the potentiometer be of fairly high resistance—somewhere between 200 and 1000 ohms, according to circumstances—in order to limit the amount of current flowing in the filament-plate circuit.

Now let us consider the effect of introducing a third electrode into the valve. This electrode is in the form of a wire gauze or perforated metal sheet and is placed between the filament and plate. It should not be difficult to see that this "grid," as it is called, can be caused to act much in the same way as a tap to a water-pipe. If its potential is positive in respect to the filament, the electron stream can pass through it to the plate; while, should its potential be negative, this stream will be checked, or even stopped entirely, owing to a dense field of electrons accumulating between the grid and filament. Again, if the grid be made alternatively positive and negative then impulses of current will flow in the filament-plate circuit.

It should be noticed that to obtain these pulses of current through the valve it must not be at saturation point. From what has already been said it should be plain that a valve with grid and plate can act in the same manner as a relay, but with

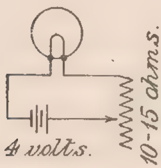


FIG. 65.

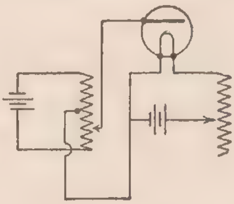


FIG. 66.

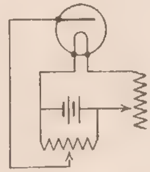


FIG. 67.

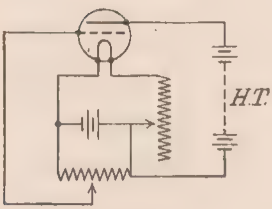


FIG. 68.

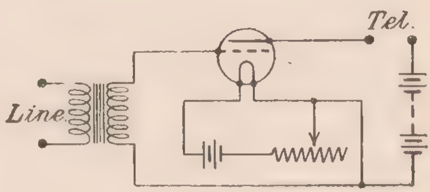


FIG. 69.

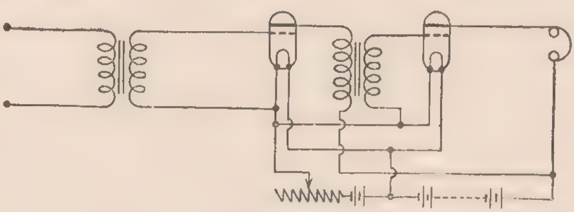


FIG. 70.

FIGS. 65–70.—Diagrams illustrating the Functioning of various arrangements of Valves.

two outstanding advantages over the ordinary polarised relay, (1) it is much more delicate in action, (2) there is absolutely no lag owing to the inertia of moving parts. It has been found necessary, in most cases, to let the potential on the plate be much greater than that used for heating the filament, so that voltages between 20 and 600 are common.

The source of current providing this potential is generally

known as the "high-tension" battery, the word "high" being used to differentiate between it and the filament or "low-tension" battery (fig. 68). How a valve may be used as a relay is shown in fig. 69, where a circuit is given suitable for a telephone receiver. It may be the messages received are too feeble for clear hearing, and by this method they can be strengthened very considerably. It will be seen that the incoming fluctuations of current forming the message are made to pass through the primary of a transformer, the induced currents in the secondary going to the filament-grid circuit; and as these small currents are of an alternating character—being induced currents from the distant microphone and induction coil—they produce corresponding fluctuations of potential on the grid of the valve. These in turn permit of rushes of current to the plate, and the current in the plate circuit—which includes the telephone receivers—is derived from a local battery, which may have considerable voltage. Consequently the magnitude of the current operating the receivers is considerably greater than that of the incoming current. Further magnification of the telephone currents can be made by causing them to operate the grid of a second valve, a small transformer being used between the two valves (fig. 70). It will be noticed that the connections are so arranged that one 4-volt battery serves to heat both filaments, and that both plate circuits are served from the same high-tension battery.

We are now in a position to study how a valve can be made to perform various functions. It has been found that if curves be plotted showing the current passing through a valve (filament to plate) under varying conditions, such as filament heating current, potential on grid, and potential in the filament-plate circuit, curves of quite characteristic form are obtained; and by studying these it is possible, by using suitable means, to cause the valve to operate either as a detector (rectifying)—when its action much resembles that of a carborundum crystal—an amplifier, or even as a generator of oscillations, These several functions are all employed, and it has been found possible, also, to combine certain of these properties in one and the same valve at the same time. Even the least-informed reader should now begin to realise the advantage of using a valve instead of a crystal detector, and also the possibilities of using a number of valves instead of

one only. A typical curve is shown in fig. 71. Suppose the filament voltage is kept constant at 4 volts, and a negative potential of 6 volts be applied to the grid; then incoming oscillations applied to the grid will be rectified, because at this point the curve is steepest on the positive side, so that the positive half-oscillations will affect the grid and cause corresponding pulses of current to flow through the valve As a detector, the valve is very sensitive, but probably not better than a good carborundum detector, its great steadiness

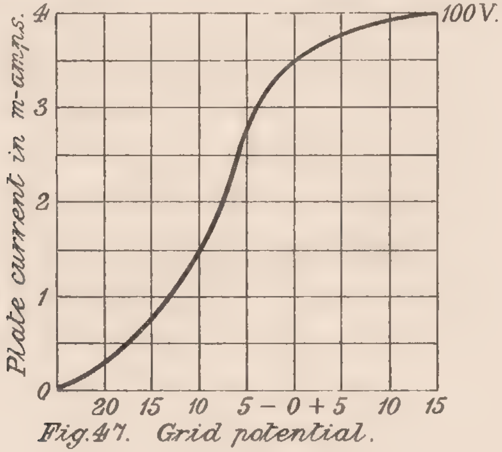


FIG. 71.—A Typical Valve Curve.

being its one great advantage. Now, if the grid potential be slightly lowered, the valve works at a lower point on its curve - a point where no rectifying effect is produced, but where the oscillations simply cause corresponding fluctuations in the valve. Hence oscillations of radio-frequency will be intensified. Now suppose the negative potential on the grid to be reduced to 4 volts. The valve will be working at a still lower point on its curve, and no current will flow through it when no oscillations are coming in. When they do, the negative half-oscillations will produce the greatest effect, so that the valve will once more become a rectifying detector, and at the same time will produce enhanced effects in the telephones. It is now a relaying-detector. As the resistance of the valve is

large it is clear that capacity effects in the circuit must be kept small, and tuning brought about by inductance effects as far as possible. The potential on the grid may be supplied by using a condenser instead of a battery of cells, but in this case it will be evident that one side of the condenser must be connected to a source of *positive* potential in order that a negative charge may be maintained on the grid. Such a condenser should be of very small capacity—about 0·0003 mfd. being the usual amount—so that it may rapidly become charged. Now, if the grid circuit has charges put into it, it is clear that charges will accumulate on the grid condenser and that these charges will tend to damp out further oscillations. In order that this may be avoided, the grid condenser is provided with a shunt resistance, so that the accumulated charges may leak away rapidly. This resistance is generally somewhere about 2 or 3 megohms, and is usually referred to as the "grid leak." A further addition to the valve circuits should now be mentioned. All the diagrams given, up to the present, have shown the telephones connected directly in the plate and H.T. battery circuit. This method has three great objections: (1) strong currents such as the H.T. battery may give off will be very injurious to the telephones; (2) as there is always some current flowing in this circuit, the telephone coils are always exercising some effect on the permanent magnets in the telephones, and it is quite possible these currents may be tending to demagnetise them through incorrect polarity; (3) it is equally possible, also, for the metal portions of the telephones to be included in the circuit with the consequent risk of shocks to the operator, or even if absolute contact is not produced, the operator's body may act as a condenser and set up undesirable capacity effects in the circuit. To avoid all this a small transformer is used, its primary being in series with the plate circuit, and the telephones placed directly across the secondary. Now steady currents passing through the primary will produce no effects in the secondary, and insulation is further strengthened. Further, the transformer is generally shunted by a small fixed condenser of about 0·002 mfd. capacity, with the result that high-frequency oscillations in the plate circuit are absorbed in the condenser, while low-frequency oscillations pass through the telephones.

It is now possible to consider how the valve can be caused

to act as an amplifier. The local oscillations, *i.e.* those produced in the plate circuit, deriving their potential from the H.T. battery, may be of considerable strength, and as they are of exactly the same frequency as those in the aerial inductance, it is possible to make them act inductively on this portion of the receiver circuits. This is done by coupling a small inductance in series with the plate circuit to the aerial inductance. This small coil is generally of the " variometer " type, that is, it may be varied in relation to the aerial inductance from the maximum coupling to a position where it is actually opposing the latter. It is generally referred to as the " reactance " or " reaction coil." Now the local oscillations will, under correct conditions, react into the aerial and its inductance, and tend, therefore, to augment the oscillations already present there ; and these augmented oscillations will, in turn, exercise greater effect on the grid. The valve is now acting as an amplifier. A complete circuit showing the reaction coil is given in fig. 72.

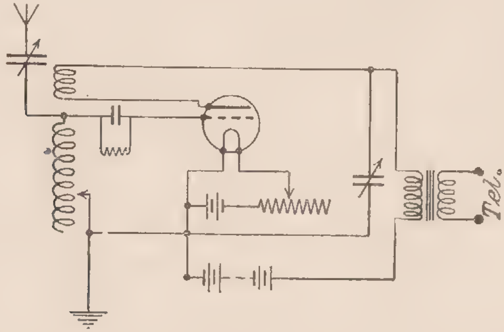


FIG. 72.—Complete Circuit showing Reaction Coil.

Reference was made to the difference between a " soft " and a " hard " valve. The traces of gas in a soft valve have considerable effect on its action. Briefly, the matter is somewhat as follows :—The gas molecules in their movements within the bulb become positively charged by contact with the plate, and are consequently repelled from it. They collide with electrons and become split up into electrons and " ions " or positively charged particles. The positively charged ions will tend to neutralise the negative field around the filament

and permit, therefore, of a much greater discharge of electrons. This means that the controlling properties of the grid are greatly diminished. Again, with higher plate voltages it is found that the great velocity of the ions, due to their attraction by the electrons from the filament, cause the latter to wear away rapidly by disintegration.

CHAPTER IX

SOME VALVE CIRCUITS

CONTINUING the subject of the last chapter, it is proposed now to deal more fully with some circuits where valves may be employed.

The first thing for the amateur to decide is how he wishes to utilise his valve (or valves), for, as has already been discussed, a valve may perform more than one function. It is necessary to provide suitable arrangements, so that the best results may be obtained in any particular case. Many who desire to make up a valve circuit will probably prefer to utilise the tuner they already have, especially if it gives satisfactory results with a crystal detector. Others will most likely prefer to make a new set right out. In order to meet, as far as possible, these conditions certain circuits are illustrated, some of which may appear, at first sight, to be but repetitions of some already given. Again, it will be necessary for the amateur worker to be prepared for considerable experiment. Conditions vary so widely that it is well-nigh impossible to give definite specifications for some particular circuit. Calculations, often very lengthy and complicated, may lead to a design which will come fairly close to the one aimed at for a definite purpose, but even then many small modifications will probably be required. Sets produced commercially are exact copies of a prototype, itself the result of considerable experiment, and these consequently give the best results when used under certain set conditions. Valve circuits may be roughly classified as follows:—(1) those for the amplification of signals as they are received, either damped or undamped, (2) those for rectifying damped waves, (3) those for producing oscillations for the production of "beats," and (4) those where

rectification and amplification take place simultaneously. As was mentioned in a previous chapter, a valve as a detector is probably not more efficient than a good crystal detector, its great advantage over the latter being its reliability and simplicity, *i.e.* as far as adjustments are concerned.

Most valve circuits involve the use of certain special items which are not included in a crystal detector. It will be as well, perhaps, to discuss these in detail before proceeding to the various circuits, as much repetition will be avoided.

Reaction Coils or Reactances.—These, as was explained previously, are small inductances which can be coupled to the aerial or other inductance. A reaction coil is infinitely variable, and indeed it may be made to oppose the oscillations in the inductance to which it is coupled. It generally takes the form of a spherical support having its surface more or less covered with closely wound coils of wire, becoming, therefore, a sort of cross between a "pancake" inductance and the usual single layer of wire on a cylindrical-former. Two forms are illustrated in figs. 73 and 74. The first is simply a wooden ball, and the amateur possessing a lathe could turn one or more to suit his own requirements. The one shown was done by a local wood-turner, is in beech, and cost, as far as memory serves, but 4d. The turner put the holes through, indeed, he suggested he should do so were any required. The second is of moulded ebonite, and is more in the nature of a ring than a ball. Details are given in fig. 75, more as a guide to proportion than for actual copying. The writer sees no reason why wood could not be used here, except that it would be most necessary to select very well-seasoned wood, otherwise trouble would certainly arise later from shrinkage and consequent cracking. It will be noticed that ridges are left on either side to provide an anchorage for the windings. In the case of the wooden balls this was done by fastening on ebonite washers, though there is no reason why they should not be formed when turning up the ball. The spindle passes through diametrically and is of brass, being fastened to the ball by a small brass plate screwed to the wood and either pinned or screwed to the spindle, so that its position may be accurately determined. The diameter of the ball should be such that it will move comfortably within the inductance without touching, and it is just as well to provide small brass bearings on the inductance-former, otherwise slackness

FIG. 73.—Reaction Coil (wooden), solid type.

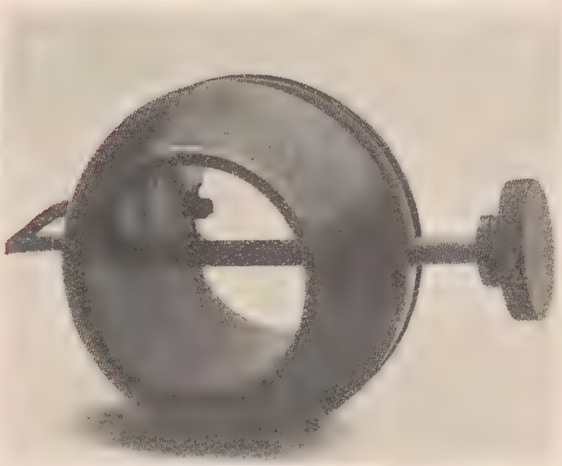


FIG. 74.—Reaction Coil (moulded ebonite), hollow type.

will occur through wear. Winding is rather a tricky business. Start at the groove and wind towards the greatest circumference. One half must, of necessity, be done at a time, and care must be observed that the direction of winding is continuous throughout. The two ends on the largest circumference are neatly joined, and the whole given a coat or two of shellac varnish. The two starting ends form the connections to the other parts of the circuit and must, of course, be flexible. The usual practice is to provide fairly long leads of light indiarubber-covered flexible wire—the lightest electric-lighting flex, minus its braided covering, serving very well. The writer has seen several attempts made to use a rubbing contact,

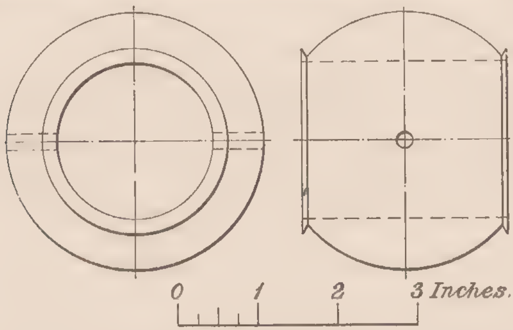


FIG. 75.—Sketch of Moulded Ebonite Reaction Coil.

somewhat after the style of a dynamo or motor commutator with its brushes. These do not seem altogether satisfactory, however, and it will be remembered emphasis was laid, in a former chapter, on the absolute necessity for really good contact in all wireless circuits. A suitable wire is No. 26, and the writer believes any reader making up a reaction coil will find single-silk or cotton-covered wire much easier to manipulate than enamelled wire. This latter wire always seems decidedly more springy than the former, and it is also very slippery.

A Grid Condenser.—This is a block condenser of very small capacity (about 0·0003 mfd.). It is easily constructed of tinfoil, with either waxed paper or very thin mica as a dielectric. Five pieces of foil, each 5 cms. by 3 cms., will be about right. The actual opposing surfaces will be 3 cms. square,

the other 2 cms. forming lugs for connection. If mica is used as a dielectric it should be very thin, and care must be taken to see that it is free from cracks or pin-holes. Let the pieces be about 5 cms. square, this giving 1 cm. clear space on either side of the foils. The best way of making up such a condenser is to lay the sheets of dielectric and foils on a thin piece of ebonite, and clamp the projecting lugs to the ebonite by thin washers and small screws passing through the ebonite. These screws will, of course, form the terminals of the condenser. Next fasten down another piece of ebonite over the whole, cutting a piece of thin card to form a distance piece all around the edges. Give this thin card a dressing of sticky varnish before clamping up, and the condenser will remain air (and damp) proof.

A Grid Leak.—This, really, is a high-resistance shunt across the grid condenser, and serves to allow the charges on the latter to escape slowly. The term slowly is, of course, only relatively speaking. The most usual value of such a resistance is from 3 to 4 megohms, and the simplest method of construction for the amateur is as follows:—On a thin piece of ebonite stick down with just a lick of shellac varnish a piece of stout drawing paper about 4 in. long by 1 in. wide. On the paper make a firm line about 3 in. long, using a BB black-lead pencil with a blunt point. At either end of the line drill a hole through paper and ebonite large enough to pass a No. 6 B.A. cheese-headed screw. Fold up some tinfoil to five or six thicknesses, put the same drill through these and then trim them up into a washer of about ½ in. diameter. Place a brass washer on the foil washer and then clamp the latter to the paper and ebonite, so that contact is made with the pencil mark. Fit a cover of ebonite, sealing it down with shellac, as in the case of the condenser, and the leak is complete. This form of leak has the disadvantage that in time the graphite at the points of contact with the foil washers becomes burnt or scattered by the discharges from the condenser, so that the resistance becomes very much higher or even infinite. Such a simple leak is, however, easily replaced. Several might be made, varying the length and breadth of the pencil marks. The one proving most suitable could then be made a standard for further leaks if necessary. The commercially-made leak is usually a length of some material having a high resistance and is free from the disadvantage mentioned above. The

most up-to-date idea is to use thin rods of glass, which is slightly conductive owing to the presence of certain metallic oxides in it.

Transformers.—These will probably form the amateur's chief concern, though there is really no great reason why this should be so. They are expensive to buy, it is true, and many amateurs will probably consider the construction of a transformer beyond them. The commercially-made article is often a really wonderful piece of work. It seems almost incredible that a really efficient transformer with a closed, laminated magnetic circuit, a primary winding of some hundreds of ohms resistance and a secondary of some thousands will go very comfortably into a waistcoat pocket. But these tiny transformers were made to occupy very little space, because that was a very important item. To the average amateur worker it is of little moment.

In Chapter V. a transformer was described for use with the telephone receivers, and the construction described there can be followed for any transformers required in a valve circuit. Such transformers are often named from the position which they occupy in the circuit ; so we have " line to valve," " inter-valve," and " valve to 'phone " transformers. They differ only in the ratio between the resistance of the two windings, except in the somewhat unusual forms of amplifier, where the line to valve transformer has its primary provided with tappings brought to a selector switch, so that the ratio in this case can be varied. The actual values of the windings vary according to the purpose of the transformer, but once these are determined there is no great difficulty in the actual construction. Wire of from 40 to 44-gauge is suitable, and not too fine for the amateur worker to handle, provided reasonable care is exercised. The covering of the wire should be as thin as possible, single silk probably being the best, and the wire should be run through a bath of hot wax as winding proceeds. Direction of winding is of no importance ; but the one great aim should be to maintain insulation as perfectly as possible. In a great number of transformers handled by the writer—and nearly all of them commercially made—the point of failure was almost invariably at the ends of the layers, that is, near the ebonite or mica-faced cheeks of the bobbin ends. This seemed to show that either a turn of wire had sunk below its correct level or that moisture had crept in at these

places. The best transformers are those where the windings are machine made on formers, and after a prolonged soaking in some liquid insulating compound are baked under pressure, and then built up on the laminations; but this method of construction is beyond the amateur. The resistance of the various windings will vary according to the purpose the transformer is to serve. The question of resistance is not the only factor determining the design of the transformer, for it is evident that were this so, it would be very simple to supply transformers of any resistance by winding them with relatively few turns of very fine high-resistance wire. The number of turns of wire must also be considered. Consequently the need for fairly fine copper wire. Having determined the resistance of a winding it is easy, by reference to a table giving particulars of wires, to ascertain what quantity of the selected wire is required. For a transformer one winding of which is to be in series with the telephone receivers, that winding should have a resistance approximately equal to that of the 'phones. Generally speaking, as was mentioned in an earlier chapter, low-resistance 'phones are used with valve circuits, and a common resistance is 60 ohms per earpiece, or 120 ohms total. In this case the resistance being low the winding would be short were fine wire used. It will be an advantage in this case, then, to use a wire of slightly heavier gauge, so that the resistance remains correct though the number of turns of wire is increased. Resistances commonly used are somewhat of the following order:—Line to valve transformers step-up from between 500 ohms and 2000 ohms on primary to between 4000 and 15,000 ohms on the secondary; inter-valve step-up from between 2000 and 4000 ohms on the primary to between 8000 and 20,000 ohms on the secondary; valve to 'phones step-down from between 2000 and 4000 ohms on the primary to approximately the resistance of the 'phones on the secondary if low-resistance 'phones are used. If the latter are high-resistance then the windings may be of equal value, or even have a slight step-up ratio.

High-tension Current.—This is, of course, a necessity, and as it is a question requiring some little consideration, the matter is dealt with fully in the next chapter.

Before leaving the question of these small accessories incidental to valve circuits, just a warning should be given with respect to the wiring of a valve set, or even a valve

circuit separate from, and used as an adjunct to, an ordinary receiver. All unnecessary crossing of leads should be avoided as far as possible, as there will be, in many parts of the circuits, currents of fairly high voltage flowing, and it is quite easy for the reactions that may be set up between various wires to cause considerable interference, to say the least, with the proper working of the set. Again, the question of good insulation, which is always important in a wireless receiver, becomes much more critical where H.T. currents are employed.

Some Typical Circuits.—We shall now proceed to consider some types of valve circuits, all of which are of a character and simplicity for the beginner to use. When he has obtained some familiarity with this portion of his work he can then experiment with circuits of greater complexity and less common form, as there are many which possess some peculiar feature, and which are used for some definite purpose. The circuits that can be employed are almost innumerable, but it may safely be said that, reduced to their essentials, they can all be grouped into three or four types.

First, valves may be employed in conjunction with a crystal, and this was probably the first development in their use. Although this combination fell into considerable disuse, there seems to be a revival of circuits where a crystal is used as a rectifying detector and a valve as an amplifier of the rectified signals ; or, *vice versa*, where the valve is used to magnify the incoming signals, and these are in their turn rectified by a crystal. As mentioned earlier, crystal detectors being quite suitable for the reception of telephony, this type of circuit is sure to become very popular. In almost all cases the carborundum-steel detector is employed. Figs. 76 and 77 illustrate two circuits of this nature. In the former, which is essentially the circuit developed by Captain H. Round, the valve is used before the crystal. This is an extremely sensitive arrangement, and will give very fine results, though the adjustments must be very carefully made. In fig. 77 we get what is practically the same circuit, but adapted to give what is known as "double magnification." This is brought about by the use of a transformer in the crystal circuit, the rectified currents being thrown back into the valve circuit, so that the telephone receivers receive the *sum* of the currents passing through the valve. It will be noted, also, that in these two

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circuits the grid potential is controlled by a potentiometer placed across the filament-heating (L.T.) battery.

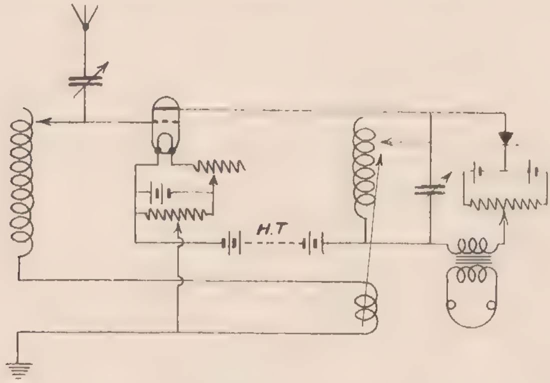

FIG. 76.—Modified " Round " Circuit.

Speaking of this, leads to a consideration of the methods employed for controlling the grid potential. There are three

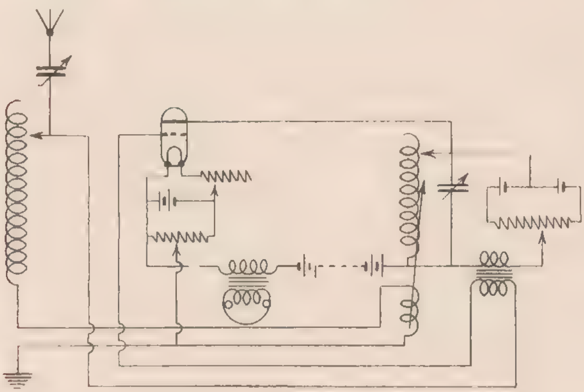

FIG. 77.—Circuit for " Double Magnification."

methods. The most usual is by the use of a small condenser in the grid circuit, the condenser being shunted by a high-resistance leak, this method being described in the last chapter. Fig. 78 shows in a simplified diagram the method of potentio-

meter control. The potentiometer is adjusted so that the grid is at the correct potential where rectification is at its

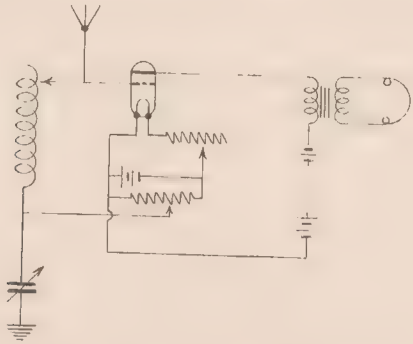

FIG. 78.—Potentiometer Control of Grid Potential.

maximum. Reference to characteristic curves will show that this is usually somewhere about -3 to -4 volts. This

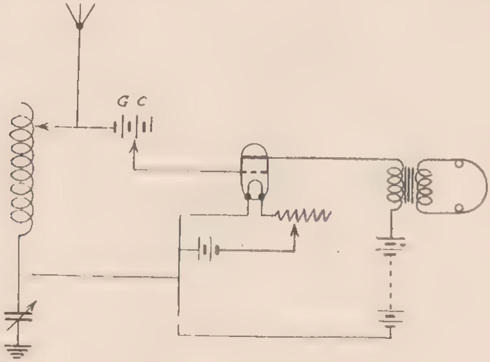

FIG. 79.—Grid Potential from Grid Cells.

method of control is most suitable for the softer varieties of valves. The third method is to use small cells directly in the grid circuit. Fig. 79 shows the principle. The cells, usually of the dry variety, are arranged in series, and a simple selector switch arranged so that the number actually in circuit

can be varied at will. In theory there would seem to be little to choose between this and the potentiometer method. It is found in practice, however, that the results with grid cells are not generally so good. This is mainly due to the fact that the varying internal resistance of the cells, together with the reactions going on within them, produce objectionable noises in the 'phones. Again, unless these grid cells are most carefully insulated from all other parts of the circuit, and even from the woodwork of the apparatus, noises are set up through tiny leakages taking place.

Crystals are often dispensed with altogether, and rectification is performed by the valve. If a valve is used for this purpose and no other, and the receiving circuit embodies no other valve, then, as was pointed out earlier, the only advantage obtained over a good crystal would be the stability of the valve in action. Consequently, when a single valve is used, it is made to act not only as a rectifier, but also as a relay or amplifier of the rectified currents. Receiver circuits using only one valve may consist of one simple circuit, or a second may be introduced and inductively coupled to the first. Many amateurs prefer a single-circuit receiver on account of its simplicity. Adjustments are reduced to the minimum, and from a constructional point of view there is, of course, some gain. But simplicity is not the only virtue of a receiver. Finer tuning and clearer signals are worth striving to obtain, and this aim is best attained by the use of a two-circuit arrangement.

For those who require the simplest of circuits fig. 80 is given. If it is required to use this circuit for reception of C.W. a separate heterodyne should be employed, or a reaction may be introduced as in fig. 85. Fig. 81 shows a circuit which may be used as an extension to the average tuner where a crystal detector is employed. The reaction coil (R) should be of the form described above, wound with from sixty to a hundred turns of wire according to circumstances, and fitted so that it may be coupled with the A.T.I. Leads from the circuit should be taken to the "stand-by-tune" change-over switch, and then tuning may be done as when using a crystal in the ordinary way. When the valve is in use the crystal should be thrown completely out of circuit. If the 'phones are high-resistance the transformer secondary should be wound to suit them, or the transformer may be omitted in this case,

though, as will have been gathered from previous remarks, this is not at all advisable. A hard valve is preferable with

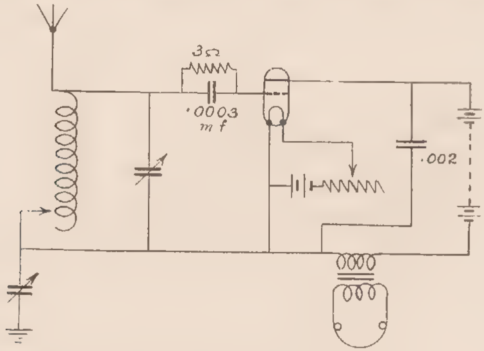

FIG. 80.—Simple Single-valve Circuit.

this circuit, and it will be found most sensitive when it is just feebly oscillating. The condenser across the transformer

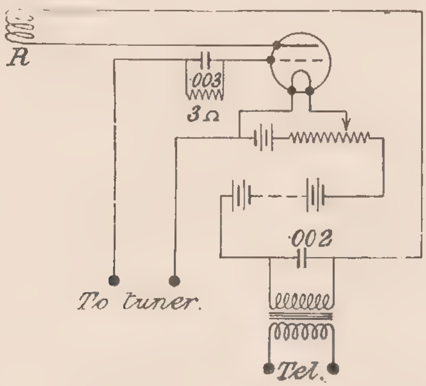

FIG. 81.—Circuit used as an Extension to Tuner when using Crystal Detector.

should have a capacity of about 0·002 mfd., while the grid condenser and its leak can be exactly as described above. Another variation where the valve will act as a detector-relay is shown in fig. 82. This circuit could be arranged to make

use of existing inductances and condensers. Fig. 83 is also a good circuit though a hard valve is preferable. This circuit is one adapted from one as described by Dr Armstrong, and as shown, a portion of the C.C.I. is used for coupling to the

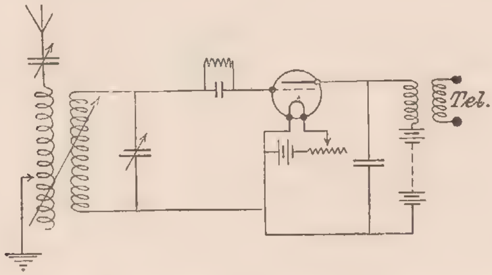

FIG. 82.—Circuit showing Valve acting as a Detector-relay.

reaction coil. Fig. 84 is interesting and is best where the reception of very weak signals is concerned. The first valve acts simply as a relay, the second performing the dual function of detector and amplifier. One L.T. battery is employed to

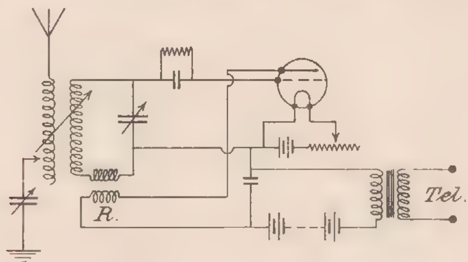

FIG. 83.—A Circuit in which a Hard Valve is preferably used.

heat the filaments of the two valves and also to provide a negative potential to the grid of the first valve. Existing inductances and condensers could be utilised as before. A circuit which gives very good results with C.W. is shown in fig. 85. It will also do very well for spark signals and may therefore be considered as a general utility set. Here, besides a reaction coil of the usual type, a second ball-shaped induct-

ance is used as a coupling between the A.T.I. and the C.C.I. The capacities of the various condensers are marked. In an experimental set constructed to the same design the A.T.I.

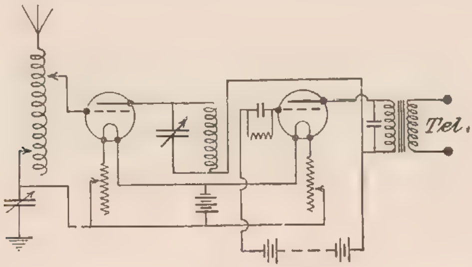

FIG. 84.—Circuit used for Reception of Weak Signals.

was a cylindrical former, 15 in. long by 4 in. diam., wound full with No. 26 S.S.C. wire; while the C.C.I. was a similar former, 12 in. long by 3½ in. diam., also wound full with wire

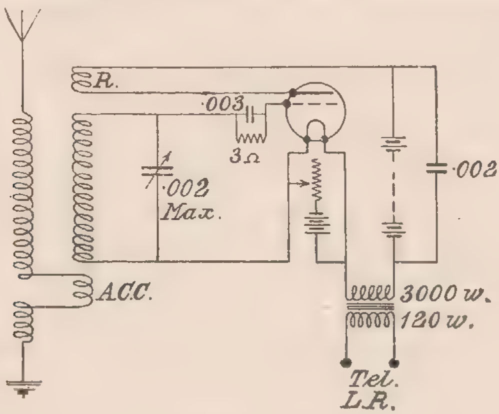

FIG. 85.—A good Circuit for all purposes.

of the same gauge. The reaction coil moved just within one end of the C.C.I., the A.C.C. (aerial coupling coil) just within the opposite end. It may be remarked that where two or more valves are worked in cascade, it is not all a necessity to use transformers to form a coupling between any two valves.

The question has often been put whether it is not possible to use coupled inductances for such a purpose in the same manner, for instance, as the aerial and closed circuits of a receiver are coupled. This is so, and it has often been done. The great difficulty lies in the multiplicity of adjustments it becomes necessary to make when endeavouring to get a particular station accurately tuned. Fig. 86 shows a circuit of this type, and is an adaptation of one devised by Dr Langmuir. The selectivity is very critical, and for this reason the adjustments must be very carefully made. By its use it is possible to reduce jamming to a very large extent, and consequently

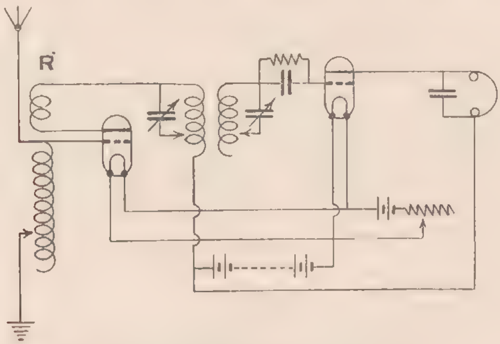

FIG. 86.—Modified Langmuir Circuit.

the circuit is often used where reception takes place on one definite wave-length. Capacity effects in the tuned circuit must be small, so that the two variable condensers need using only to give the final crispness to the tuning. The most necessary requirement is that the plate circuit of the first valve shall be in exact resonance with the grid circuit of the second.

Beginners are often confused as to the difference between receivers (using a valve or valves) and amplifiers, and also between the terms "high frequency" (H.F.) and "low frequency" (L.F.) amplifiers. Strictly speaking, an amplifier is an apparatus the only purpose of which is to magnify or strengthen signals which are too weak to be usable when the ordinary detector is employed. Amplification may be obtained before the detector is brought into use, or it may follow

on after the signals have been rectified. This has been mentioned earlier, and is repeated in order to give point to what follows. Oscillations as they are received in the aerial circuit must be modified in some way before they become audible because their frequency is too great. Those amplifiers which deal with the received oscillations before rectification takes place are generally termed high-frequency amplifiers. Those which strengthen rectified currents, or it may be, weak telephonic messages, are termed low-frequency amplifiers. The majority of amateurs use the low-frequency method because of its simplicity, and also because the apparatus requires less attention. The method of coupling the valve circuits is to use iron core transformers. These are easily obtained, and

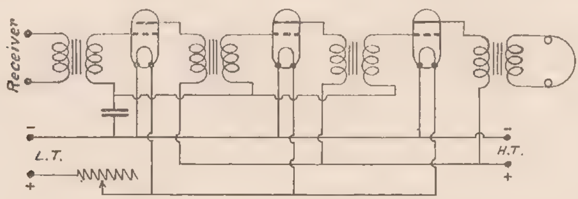

FIG. 87.—Wiring Diagram for 3-Valve Amplifier.

connecting them into the circuits is a simple matter. The use of such transformers is not possible where high-frequency currents are concerned, so that other methods must be adopted. Fig. 87 shows what is about the simplest and most satisfactory lay-out for a three-valve low-frequency amplifier of the usual inter-valve transformer type. Fig. 86 is an example where magnetic coupling is employed. In fig. 87 we have an example of what is termed the resistance-capacity method. Here, transformers between the valves are absent, their place being taken by high resistances and small condensers. The method offers the very great advantage that weak signals are amplified to a much greater proportion than strong ones. For this reason there is a great reduction in the amount of parasitic noise so commonly met with in circuits where low-frequency transformers with iron cores are used. This amplifier provides for rectification and amplification. In circuits of this nature the degree of amplification is largely dependent on the amount of capacity introduced. The resistances being

great, account for a good deal of energy, and condensers larger than 0·00005 mfd. as maximum are not desirable, and they should be variable. These high resistances are best purchased. Most dealers can supply them in the form of rods to practically

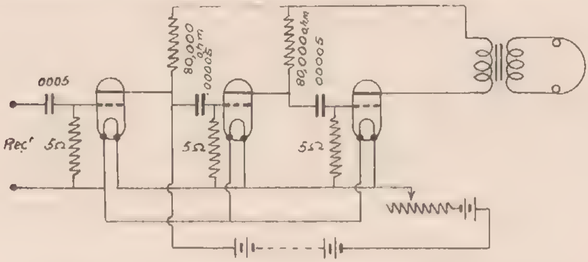

FIG. 88.—Circuit with Resistance-capacity Coupling.

any requirement. The rods are provided with tight fitting clips and are quite stable in use. They are not expensive. Fig. 89 illustrates a simpler form of the same type of circuit; but this is not very suitable for short wave work. Fig. 90

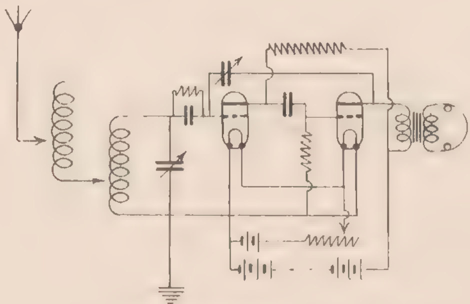

FIG. 89.—Another Resistance-capacity Coupling.

shows a resistance-capacity amplifier for low-frequency work, and it may be connected to any receiver which will provide the necessary rectification. Resistances 1, 2, and 3 should be about 50,000 ohms, while 4 and 5 should be in the neighbourhood of 200,000 ohms. The latter two resistances take the place of the leaky condensers between the 1st and 2nd, and 2nd and 3rd valves. The condensers 6, 7, and 8 are all fixed,

and of about 0·0003 mfd. capacity each. The first two provide energy to the grids of the 2nd and 3rd valves, while the third serves to protect the telephone receivers as these are connected directly in the H.T. circuit. It is extremely important to maintain a high degree of insulation in this type of circuit, and it is never advisable to cramp such an amplifier into a small space. Where iron-core transformers are used, the magnetic fields are strictly confined to the iron work. In fact, in a well-designed transformer it should be difficult to detect much in the way of stray magnetic fields. In the case of resistance-capacity coupling this is not so, and unless all the components of the circuit are well spaced undesirable noises, and possibly irregular working, are certain to be set up. An amplifier of

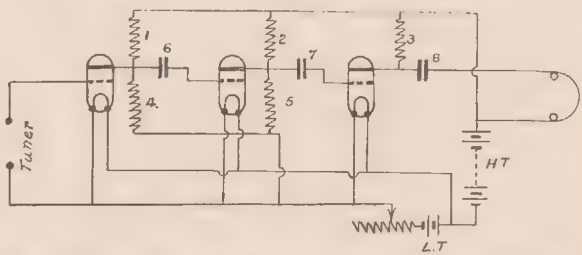

FIG. 90.—An Amplifier with Resistance-capacity Coupling.

this type is not quite equal to a low-frequency amplifier where inter-valve transformers are used; but this, to some, would no doubt be compensated for by the simplicity in construction and the saving in expense. The avoidance of transformer breakdown is also eliminated.

Attempts have often been made to replace the high resistances used in this type of amplifier by coils having a high impedance value—in other words, choking coils. They do not seem to be altogether successful, and many difficulties stand in the way. In the first place, it is an extremely difficult matter to produce a satisfactory design for choking coils which have to deal with high-frequency oscillations. Then, there is also the difficulty of suiting the impedance to the particular wavelength on which reception is taking place.

A further method of high-frequency amplification, and one to be much recommended, is to use what is termed a "high-frequency transformer." This consists of two coils of wire

closely wound one over the other, or side by side, but without an iron core. In Chapter XI. there is a detailed description of such a transformer. Reference to this will show that by suitable switching arrangements the total amount in each coil may be varied according to circumstances. Many amateurs prefer to have a set of self-contained transformers each covering a definite range of wave-lengths, much in the same way as a set of slab inductances is used. A very simple method of making up these is to turn a groove in the edge of a disc of ebonite and to wind in this a few yards of fine S.S.C. wire—about No. 42 or 44 S.W.G.—for each side of the transformer. If the wire is run through hot wax no other insulation will be needed. The amount of wire is best found by experiment, as it is not at all an easy matter to give a rule whereby the amount may be calculated. Fig. 91 shows a circuit where such a transformer is used (marked H.F.T.). Such a circuit will deal very successfully with very weak signals.

When discussing the reception of C.W., in Chapter VI., it was pointed out that the most usual method is to arrange for the production of beats, a valve supplying the necessary energy in the form of oscillations, which are a little different in frequency to the incoming oscillations. This is often spoken of as the "heterodyne" method, and the effect may be produced in two ways. In one, the most usual among amateurs, the one valve is made to carry out all the functions; while in the other an entirely separate oscillatory circuit is used, this being tuned to a different frequency to the receiving circuit, and then coupled inductively to it. The former method is generally termed the "self" or "auto" heterodyne, or sometimes the "autodyne," and all the circuits illustrated above, where a reaction is provided, are such. While this is no doubt the simpler method, it is open to the serious disadvantage that the aerial itself is caused to oscillate and so radiate energy. In unskilled or careless hands this method is likely, therefore, to cause trouble to other operators within a considerable area. Many readers who have done a fair amount of reception during the last two years or so will doubtless call to mind many instances where they have experienced interference of this nature. The amateur should, then, take every means possible to reduce the production of such interference, otherwise it is likely that the whole body of amateur wireless workers may suffer from the imposition

of more stringent regulations instead of the more favourable conditions for which they are hoping. The use of a separate or "ultra" heterodyne, while producing better results, especially on long waves, helps in the prevention of interference. The objection raised by some amateurs to its use is that it involves the provision of extra apparatus, including a valve, and a greater expenditure of H.T. and L.T. current. This is true, but it is questionable whether the advantages obtained by the much better signals obtainable, together with the diminished interference, do not outweigh the objection. A simple oscillatory circuit where the oscillations are generated

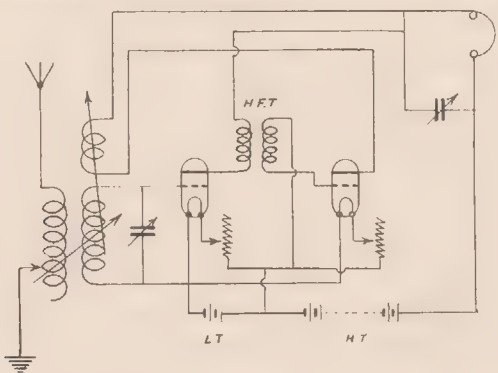

FIG. 91.—A Circuit employing a H.F. Transformer.

by a valve is loosely coupled to some portion of the receiving circuit as remote from the aerial inductance as possible. In single circuit receivers this is not feasible, while the only method where coupled circuits are employed is to couple the ultra-heterodyne to the secondary inductance. Fig. 92 shows a simple generating circuit which may be coupled to the receiving set in the manner described. The two inductances (in the generator) should be as tightly coupled as possible. They could very well take the form of a pair of slab inductances permanently mounted together. The reader must decide for himself over what range he will require the generator to be used, and calculate the grid inductance accordingly. As the inductances are not variable in use, adjustment is made by the condenser which should be large in order that a long

range is permissible. A hard valve is most suitable, and it will be found that the H.T. volts will be hardly likely to exceed 20. It is often possible to reduce radiation very considerably, even when auto-heterodyne is used, by judicious arrangement

FIG. 92.—A Simple Generating Circuit.

of the receiver circuits. Fig. 93 shows quite a good arrangement for this purpose. In Chapter VI. it was shown how C.W. might be received by a crystal detector, provided the incoming oscillations were broken up. An ultra heterodyne serves this

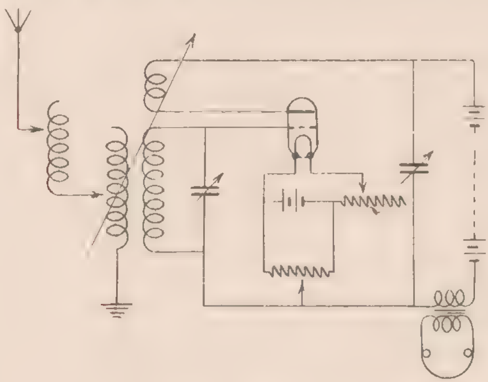

FIG. 93.—A Circuit of Low Radiation Value.

purpose admirably, and provided adjustments are nicely made, the signals are often of much better quality than when using an auto-heterodyne arrangement.

Circuits for Short Wave Reception.—The average amateur seems, for some reason or other, to devote a great deal of time and experiment in adjusting his set to receive signals from those distant stations which usually radiate considerable

energy on very long wave-lengths. He is not nearly so keen on picking up signals on a wave-length of much below 3000 metres. But it is fairly safe to say that greater manipulative skill is required to pick up, and tune in exactly, signals on short wave-lengths, than those of the great government or commercial stations. Many amateurs when asked to explain this preference, state that they have great difficulty in exactly tuning short wave-length signals, and that when they do get them tuned they are very weak. Now the main reason for this is that the reception of short waves requires somewhat different treatment, and certainly a much nicer adjustment of inductance and capacity. Generally speaking, the amateur makes the mistake of expecting his set to do too much. How often one sees the inquiry for a design for a circuit capable of receiving signals from 200 metres up to somewhere in the neighbourhood of 30,000 metres. While not going so far as to say no set can be expected to give such a range, it is quite safe to say that it would be much better to have two sets, or one set capable of being divided so as to constitute two sets, and to use one for waves, say, up to 3000 metres, and the other for those of greater length. It may be possible on one and the same set to definitely receive signals at any point on the whole range, but it is a certainty that the signals will not be of equal sharpness and strength throughout.

Again, it is a great mistake, no matter what form of set is employed, to add an extra valve to strengthen signals, unless one is absolutely certain that those signals cannot be improved further with the set as it stands. The writer has seen two sets, one using a single valve and the other four, worked off the same aerial and receiving from the same station, the results from the former being much more satisfactory than those from the latter ; not *louder*, perhaps, but much more distinct. As mentioned earlier, there is a vast difference between loud noises and clear distinct signals.

It is intended to close this chapter by indicating some devices especially applicable to the reception of short waves. In the first place, it may be stated that a single circuit receiver is not likely to give the satisfaction that can be obtained by employing one with two inductively coupled circuits. This is because the two-circuit receiver is much more sensitive and has far greater selectivity. A single circuit involves much less constructional work and is more easily manipulated,

perhaps, but it will be found that a little experimenting with a two-circuit receiver on short waves will provide quite an education, and a great amount of experience and pleasure.

As very fine adjustments are necessary, it might be as well for the experimenter to look around his available apparatus to see what alterations or additions may be necessary. Variable condensers he will no doubt possess, and they will serve if in good order. It will be a great acquisition if he can

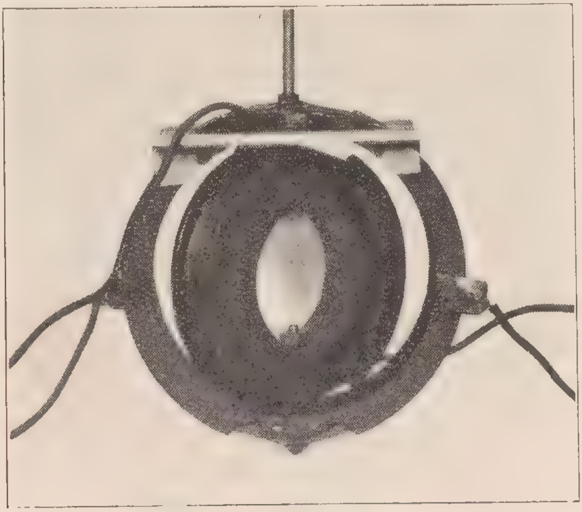

Fig. 94.—A Variometer.

add one or two of what are often termed "vernier" condensers. These are simply variable condensers of extremely small total capacity. Generally, they have but one movable vane, and the total capacity is about 0·00005 mfd. The "billi" condenser mentioned earlier comes under this category. Another very valuable item is a variometer, by which very fine adjustments in coupling can be given. This piece of apparatus is often incorporated in an existing inductance, but is preferable as a separate unit. It is not at all a difficult job to make up one, and an example is illustrated in figs. 94 and 95. It consists of two ebonite rings, one fitting within the other. The inner one is mounted on a spindle passing diametrically

through both, and so can be rotated. Both rings are wound with the same length of wire of similar gauge, and the two windings are connected in series. The leads from the inner ring, or rotor as we may call it, may be of thin insulated flex, or provision may be made to let the bearings act as terminals (the method adopted in the variometer illustrated). In this latter case it is obvious that the spindle must not be continuous, but in two portions. The amount of wire on the variometer must depend on the work it is required to do. If, for example, a set is designed to work over a long range of wave-lengths and a variometer is included in the inductance, then, whatever the total amount of wire on the variometer, it will not be suitable for both limits of that range. If suitable for the long waves there will be too much for the short waves, and *vice versa*. Instead, it is much better to divide the inductance by providing tappings from it, and to let the amount of wire on the variometer be a little more than that included in one division of the inductance. Examination of the action of a variometer will show that in its normal condition, *i.e.* with the rings in the same plane and the windings proceeding in the same direction, then the two windings will act inductively on each other. As the rotor is turned this reaction will become weaker and weaker until the 90° position is reached. This may be called the zero position. Any further movement, will place the windings in opposition to each other, until when the 180° position is reached and the rings are again in the same plane, each will be actually cancelling the effects of the other. A reaction coil, so commonly used in valve circuits, is simply a variometer, and many amateurs who experience difficulty with their sets will find that the fault often lies in the amount of wire they have on the reaction coil. The amount should be the least possible, or trouble from resonance effects will certainly occur, especially on short-wave reception. It is possible, also, that a reaction coil or variometer may be in-

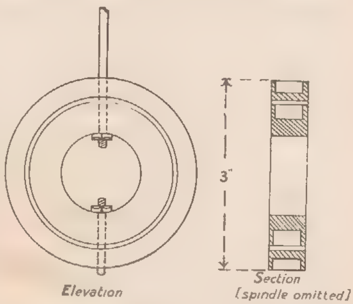

FIG. 95.—Details of Variometer.

correctly placed in the circuit of which it is part. Movements of the reaction coil are bound to affect tuning, and the disturbance will be greatest where the highest potentials obtain. For this reason then, it is preferable to couple the coil to that end of the inductance connected to the filament and not to that connected with the grid of the valve. Placing it in this position will lessen considerably those effects so noticeable when the hand is moved about the valve, or those parts of the circuit connected closely to it. This point is worth special attention in those sets designed for the reception of telephony.

Fig. 96 is a modification of the Armstrong "regenerative" circuit, and is a type of circuit very popular in America. It

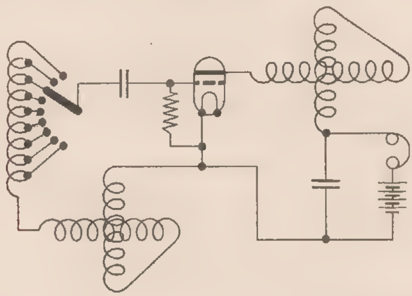

FIG. 96.—Modified Armstrong Circuit.

will be seen that both the plate and grid circuits are tuned by variometers and no separate reaction is used. The aerial and grid circuits are set to the wave-length required, and tuning is done on the plate circuit. As soon as this is almost within resonance the set will commence to oscillate automatically. No further tuning should be made, or howling will most probably commence. It will be noticed in this circuit that the grid leak is not across the grid condenser, but across the grid and the negative side of the filament. Fig. 97 is another very good circuit, and those readers who have by them the once popular two-slide inductance and sliding coupled inductances can make use of them to advantage. Two will be required, one—the sliding type—for coupling the aerial and grid circuits, and the other—the slider contact pattern—to couple the grid and plate circuits. These two circuits are therefore coupled by what is virtually an auto-transformer.

In action, a difference of potential is set up between the grid and filament, so that energy is fed back from the plate circuit into the grid circuit. Suitably adjusted, the set can be made to amplify by reaction, or to self-oscillate for C.W. reception. An extremely sensitive circuit, and one especially good for telephony, is shown in fig. 98. Although using a fair number of adjustments, it is so selective in action that it is almost an

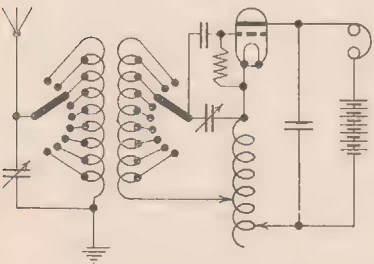

FIG. 97.—Circuit utilising Coupled Inductances.

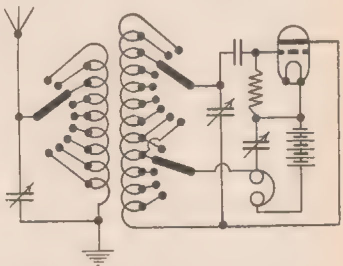

FIG. 98.—A good Circuit for Short-wave Telephony.

ideal set for the worker who desires to explore a long range of short wave-length signals. The A.T.I. can be tuned by tappings throughout its whole length. From the secondary inductance two sets of tappings are taken, that for reaction adjusting embracing only about one-quarter of its length. It will be seen that no movement of the reactance is necessary as it forms part of the inductance. Critical control of the reactance is brought about by using the least possible amount of the variable by-pass condenser shunting the H.T. battery and 'phones.

CHAPTER X

HIGH-TENSION CURRENT SUPPLY

THE use of valves makes the source of a current of high potential (or tension, as it is ordinarily termed) imperative, and the question of H.T. supply is often for the majority of amateurs a serious problem. After the initial outlay on a receiving set it is probably the most serious item in upkeep,

and therefore well worth the user's consideration and, it may be, experiment. The increasing use of valves as detectors and amplifiers, and this latter often in several stages, has emphasised the need for the utmost efficiency in H.T. current if anything like true economy is to be obtained.

The H.T. supply to valves used in reception work must possess certain definite qualities. It must be D.C. or its equivalent, its voltage may have to range from 20 to perhaps over 100, and that voltage must be absolutely steady. The amperage also, at any given voltage, must not vary, and the supply must be available at short notice, and perhaps irregular intervals. Excluding one or two sources of supply which, at present, are hardly within the amateur's scope or have barely passed the experimental stage, there are but two solutions to the question, (1) a supply generated by some mechanical or physical means, or (2) that from some form of cell either primary or secondary.

It would seem at first sight not a difficult matter to use current from a dynamo; as for example, public supply mains. But, as many readers will be aware, the mechanical effects of the commutator of the dynamo become very pronounced where valve working is concerned. There are means of overcoming this difficulty, but it is questionable whether many amateurs would consider these means a desirable addition to their other apparatus; and if the experimenter decides to use his own dynamo there is always present the fact that he must provide some means of driving it.

Under the term physical means, the writer would place the use of a thermo-generator. This form of current generation possesses some fascinating problems all its own, and the writer does not recollect ever having seen the suggestion put forward for the use of a thermo-generator for the purpose under notice. Various attempts have been made to produce a "thermo-pile," as it is often termed, suitable for commercial use, or rather as a commercial proposition. There are many difficulties to be overcome in the successful use of a thermo-pile, especially if current is required in anything like bulk. But where the current necessary need never be of great amperage, there seems no reason why this form of generator should not answer. True, the voltage per couple is almost always very small—somewhere about 0·08—but then the couples need not be large, so that the generator would not be of great dimensions.

The use of cells is, undoubtedly, the most popular method of providing H.T., and the familiar pocket-lamp battery, either as such or an adaptation, the most widely used type. Pocket-lamp refills are easily obtained, at prices somewhere around ninepence each; and reckoning that each one when fresh should show a voltage of 3·9, it is a simple matter to make up a battery to give the total voltage required. It is presumed here that the refill is of the type containing *three* individual cells. Working on this basis we may draw up a table of reference as follows:—

Voltage	15	requires	4	refills.
,,	30	,,	7	,,
,,	40	,,	10	,,
,,	60	,,	15	,,
,,	75	,,	19	,,
,,	90	,,	22	,,
,,	100	,,	25	,,

Fig. 99 shows a convenient method of arranging a number of such refills, and providing tappings for different voltages. Each refill should be painted over with melted wax as a precaution against short-circuiting, or leakage. Batteries made up in a similar way are obtainable from any good dealer ready-made, and arranged to give either a definite total voltage, or provided with tappings. For general convenience there is perhaps nothing to beat such batteries. There have been one or two departures from this general practice, and quite recently a correspondent to the *Model Engineer* described a simple form of the gravity type of Daniell cell which he was using. Personally, the writer believes this form of cell to be unsuitable, on the ground that this particular kind of cell should never be allowed to stand for long on open circuit, otherwise a chemical reaction takes place within it, copper being deposited on the zinc element with consequent stoppage of current. Then, again, it must on no account be disturbed, though this is not so vital a consideration. Again, from a point of view of economy this type of cell would not appear to score. Two of its essential parts, the zinc and the copper sulphate crystals, are consumed, and as both are fairly expensive, upkeep will prove a consideration. From the standpoint of efficiency and economy the Leclanché—or its "dry" modification referred to above—still remains well in front. The three dis-

advantages attaching to the latter are: (1) its liability to polarise if worked at too high a rate, or for too long at a time; (2) the

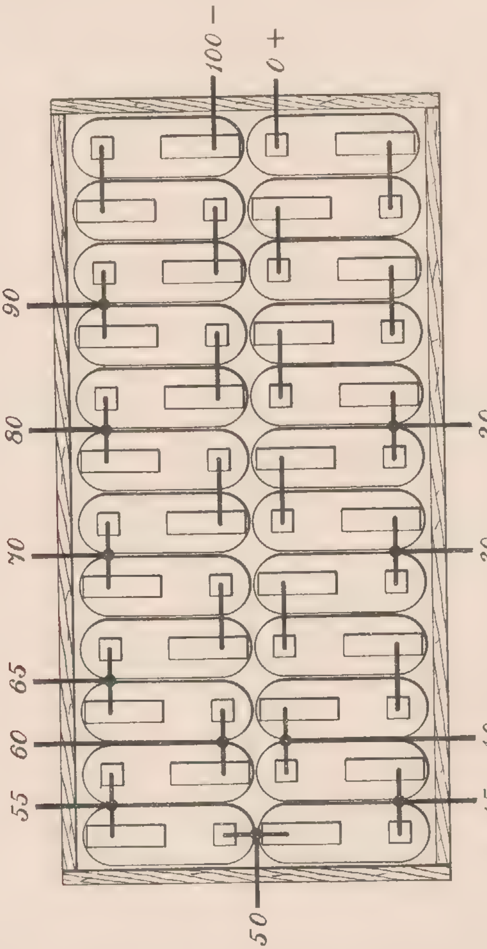

FIG. 99.—A Group of Dry Cells arranged to give "High-tension" Current.

difficulty of ascertaining its remaining useful life at any particular period; and (3) its liability to deteriorate when out of use. The wet form overcomes the latter two disadvantages.

The general procedure of the amateur is somewhat as follows:—He obtains a sufficient number of dry batteries, either of the flash-lamp variety or those of larger dimensions so widely advertised, and uses them till a drop in total voltage indicates that failure has occurred in one or more individual cells. Then he either cuts out the faulty ones, or obtains a new set. When a dry cell does go wrong, it may be taken for granted as a general rule that either the zinc element is entirely consumed, or that the exciting chemical has ceased to be effective. Occasionally a cell may become so dry that its internal resistance increases so enormously as to reduce the voltage of the remainder to a negligible quantity. This is rarely the case, however; generally the cell as made to-day becomes more and more damp, and this dampness extends from cell to cell, effectively short-circuiting those involved. The carbon element and the depolarising agent packed around it are as good as ever, in all probability; in fact, they will remain effective for years. And the question naturally arises, Is it possible or worth while trying to use those good portions still further? In the majority of cases the answer is decidedly in the affirmative. On breaking open a discarded cell, after removing the remains of the zinc and the excitant, one comes to a little linen bag containing a fairly hard block of black material. This is not always the case, as the bag is not used by some makers; and in this case there is little hope of renovation. Now, if these little bags be removed intact and then given a soaking in a 5 per cent. solution of sulphuric acid for half an hour, it will be possible to remove practically all encrustation. A further soaking in two or three changes of the water will leave them quite clean, and they may then be allowed to dry. Next remove the little brass cap from the head of each carbon. These usually come off quite easily, as the sulphuric acid will have acted fairly strongly on them. Their removal is necessary, as sal-ammoniac corrodes them very rapidly, and the consequent corrosion will introduce a very high resistance, causing intermittent or complete stoppage of circuit. Instead, wind around the carbon three or four turns of fairly fine copper wire, about No. 30—and then well solder the wire. As the solder cools it will contract, making good contact, and solder is hardly affected by sal-ammoniac. The simplest method of carrying out this soldering operation is to dip the wire-wound heads of the carbons into a solution

of resin in methylated spirit, and then immerse them in a bath of melted solder. Now prepare pieces of sheet zinc of the shape (either A or B) as shown in fig. 100. Shape A is the simpler to construct, though B will give longer life. These zincs should be amalgamated. Some amateurs do not consider this necessary, but the writer is certain that many of the queer noises in the 'phones are due to local action taking

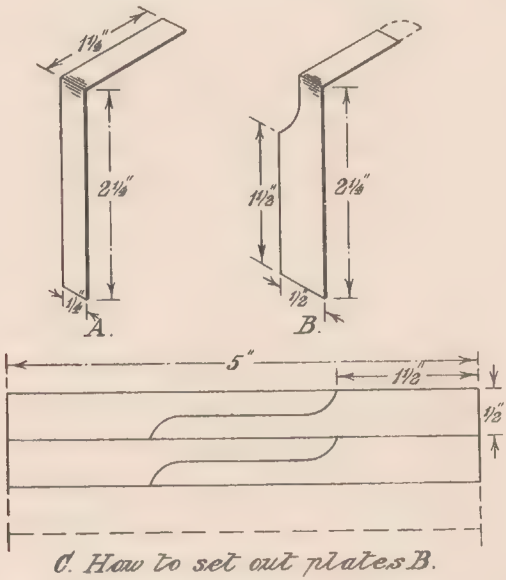

FIG. 100.—Shape of Zincs for H.T. Battery.

place in the zincs. This local action it should be remembered, too, is going on even when the cells are not in actual use, so that here we have a direct source of waste. Commercial zinc is impure, so that local action is bound to occur unless the metal is amalgamated, or chemically pure zinc is used ; and this is out of the question on the score of expense. If it is considered advisable to amalgamate the zincs of cells destined for such an ordinary purpose as ringing bells, it is surely more necessary to do so in our case. The amalgamation is best done by immersing the zinc for a few minutes in a solution of

mercury nitrate, or by rubbing a little mercury on it while it is wetted with very dilute sulphuric acid. Whichever method is adopted, the amalgamation should be only slight, as a heavy application of mercury will cause the zinc to become exceedingly brittle. Now comes the question of cells. Short wide test-tubes can be obtained, but these seem still to be relatively expensive, and in some sizes difficult to obtain. A good substitute may be provided quite cheaply as follows :- Prepare strips of paper to the dimensions shown in fig. 101, this size being suitable for cells of the flash-lamp battery type. Slightly damp the paper, put a spot of glue on one of the points and then roll up tightly on a smooth round mandrel of at least 1 in. diam. A wooden ruler, or such like, answers very well, though the writer uses a test-tube which, although rated as of 1 in. diam., is really $1\frac{1}{8}$ in. At finishing, a spot

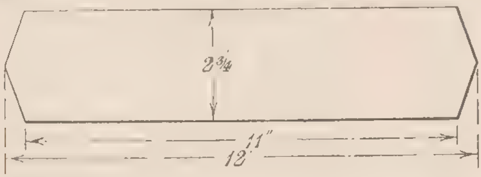

Fig. 101.—Outline of Paper for making Small Cells.

of glue on the other point will secure the end. The reason for using but a spot of glue is that a glued seam will not allow the wax to permeate the paper, and leakage or deposition of crystals will certainly occur later. Good, thin brown paper will serve, though the cells illustrated are of thin, hard cartridge paper. Allow the paper tubes to dry, and then, if necessary, go round them with a keen knife, trimming them to a length of $2\frac{3}{4}$ in. Using a test-tube as described, a beautifully clean edge is produced. The tubes should now be slid off the mandrel and baked in a moderately hot oven for half an hour or so, to remove all traces of moisture. Upon removal from the oven they should be immersed straight away into a bath of melted paraffin wax which is kept at a temperature where it is just smoking. As soon as all bubbles cease issuing from the paper, each tube is placed directly in position on the baseboard which has already been prepared. The surplus wax will flow to the bottom and cement the tubes to the baseboard. This board is of a size to accommodate the number

of tubes desired, leaving about $\frac{1}{4}$ in. space between each. A piece of good sound wood about $\frac{3}{4}$ in. thick is marked out, and then with a $1\frac{1}{4}$-in. centre-bit circular cavities about $\frac{1}{4}$ in. deep are formed. Should the point of the bit penetrate the wood it is as well to plug up the small holes with short pieces of wood. When the paper cells are all firmly set, sufficient very hot wax is poured into each to form a layer about $\frac{1}{4}$ in. thick at the bottom. This method will be found to produce a very strong and satisfactory job. This operation can be simplified in the following way:- While the tubes are soaking in the wax, pour into three or four of the cavities sufficient nearly boiling wax to fill them. The tubes may now be removed from the wax, and placed at once in position. The two lots of wax, being both very hot, will set together forming a perfect joint. There need be no fear of these cells deteriorating under the action of the sal-ammoniac, as wax is a most efficient resistant to this substance. A sample cell was immersed in a strong solution for a lengthy period and showed no trace of rotting.

The prepared elements can now be put into position, carbon in one cell and its attached zinc in the next. The solution is made up by dissolving 2 or 3 oz. of sal-ammoniac in a pint of water, which has been previously boiled. The voltage of the cells varies slightly with the strength of the solution, though a strong solution is more likely to produce crops of crystals or insoluble salts in the cells. The use of a good quality sal-ammoniac is recommended, and the liquid should be introduced with a finely-pointed glass funnel or pipette, until its level comes just to the shoulder of the bag surrounding the carbon. A little shrinkage may take place, as the dry element will absorb a small quantity. A few drops added later will put this right, though any subsequent shrinkage, due to evaporation, should be made good by the addition of water only. The battery shown in fig. 102 is of forty-eight cells, made up exactly in the manner described. They show a total voltage of 54, and stand up to a discharge of about 0·1 amp. for half an hour or so quite easily.

It is important in making up these cells to allow plenty of room between the positive element and the zinc. This is of course determined by the diameter of the paper tube. In the first set made up, the writer found quite a number of the cells soon choked up with a pasty mass of chlorides, etc.;

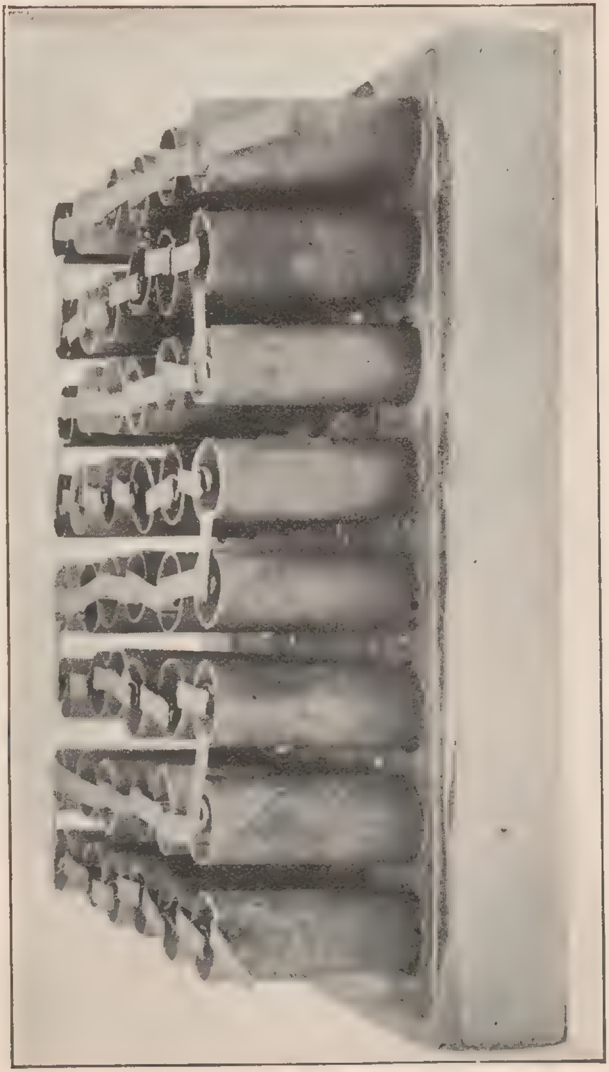

FIG. 102.—48-Cell H.T. Battery.

evidence that there had been considerable internal action going on, due to the zincs touching the carbon elements. The voltage of such cells is practically zero, while their internal resistance is relatively large. In course of time the zincs will need renewal. This is an easy matter, and at the same time it would be as well to remove the old solution and fill up with fresh. The zinc passes into combination with the sal-ammoniac forming complicated double chlorides, and as these are not very soluble, a sort of mud is formed at the bottom of the cells and round the carbon. Removal is easy if taken in time, but difficult if delayed as the deposition sets into a hard cake. Figs. 103 and 104 show a further development of this method of renovating old dry cells. The positive elements in this case were taken from torch refills where the three cells are placed one above the other. They were treated in exactly the same manner as the smaller kind, and the containing jars are little glass pots in which a well-known pickle is sold. The zincs, as will be seen, are much larger, being almost complete cylinders. Corks, well soaked in wax, are provided to aid in preventing evaporation and also to keep the zincs spaced from the positive elements. The voltage of these cells is no more than from the smaller ones, but their much greater size allows of a much heavier current being taken from them, or they will remain steady over a much longer period if only a small output is demanded.

So much, then, for primary cells; and in concluding this section it might be remarked that those readers who use larger dry cells can adopt much the same procedure with these when they (the cells) cease to be useful in their original form. Remove the card or paper cases and as much as possible of the white substance placed over the block of depolariser. Then, if this block seems to fall to pieces, inclose it in a wrapping of linen, or better, what is known as butter-muslin. Place this block in a small jam jar, fit a sheet of zinc (amalgamated) round it, fill up with sal-ammoniac solution, and a cell as good as the original will result.

The possibility of using secondary cells of very small size was discussed at some length in two articles in the *Model Engineer*,[1] and in this connection it is interesting to note that small accumulators for valve working are now appearing

[1] *Model Engineer*, **41**, 220; and **43**, 323.

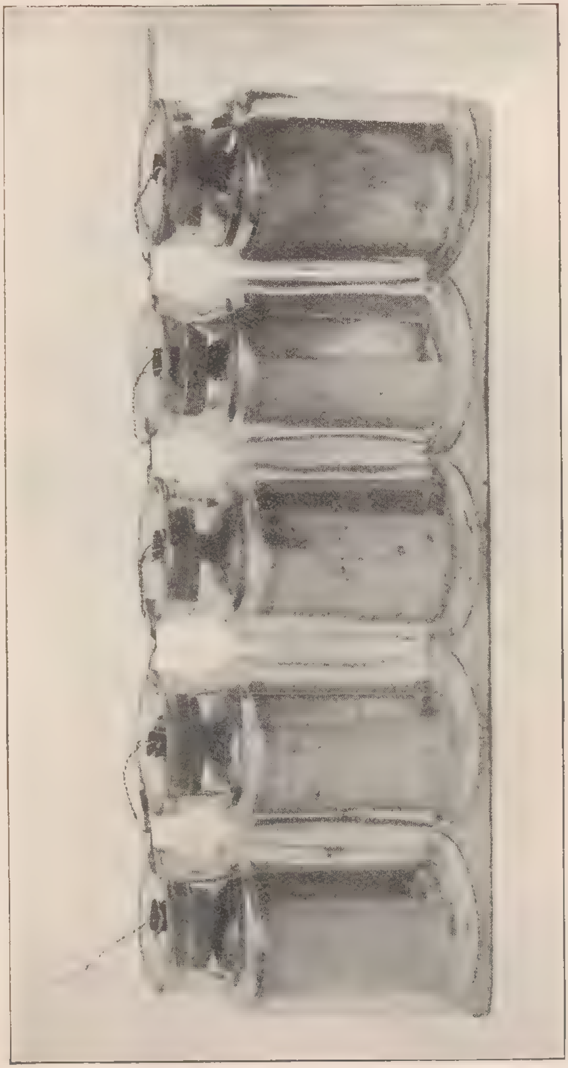

FIG. 103. Small Cells for H.T. Battery.

on the market. The writer has come across, too, several instances where amateurs have followed up the idea with entire satisfaction. The cells in question were entirely home made, the grids being cast in a simple mould. As cast, the grid is too wide and is therefore cut up the centre, thus yielding two grids, each about 5 in. long by ½ in. wide. These are then filled in with paste, which can be made up in two methods. For the positives, red lead of good quality is mixed to a putty-like mass with a 20 per cent. solution of pure sulphuric acid, and

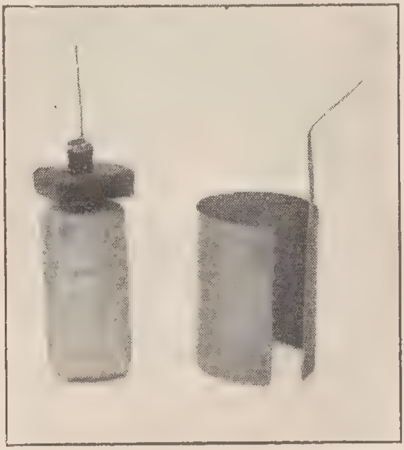

FIG. 104.—Zinc and Carbon Element of Small Cells.

this well pressed into the grid. For the negatives, a similar paste of litharge and acid is used. Alternatively, the paste may be made up from the old paste knocked out from discarded plates, provided it is not contaminated with sulphate. The addition of about one-third of red lead, or litharge, as the case may be, to the old powdered paste is advisable (fig. 105). After pasting, the plates are allowed to dry thoroughly for a few days, and then temporarily soldered up in batches to a strip of stout lead, so that as many as possible at a time may go through the forming process. Batches of positives and negatives are placed in old accumulator cells, just as though they were complete plates, and then charged at a low rate for

about thirty-six hours. They are then discharged through a lamp of suitable voltage, and again recharged. After three or four such charges they are unsoldered, and any faulty plates discarded. The now formed plates are now connected in pairs —positive and negative—by narrow strips of lead "burnt" to the lugs. The term "burnt" is a trade name for autogenous soldering; that is, the metal is united, using lead as a

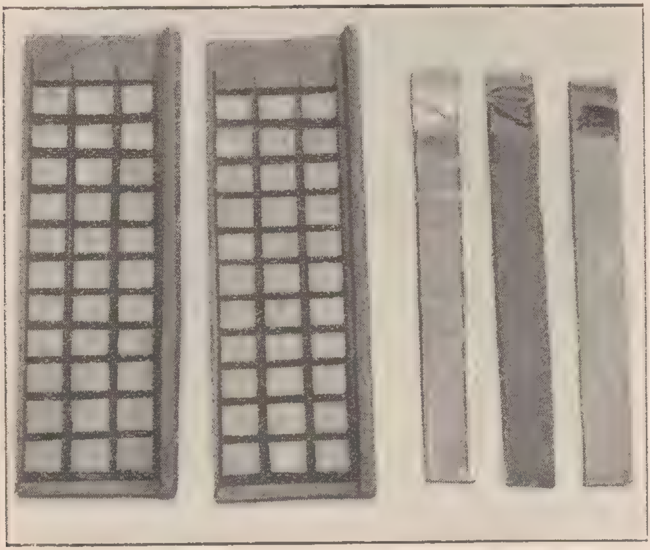

FIG. 105.—Moulds, Grid, and Finished Plates for H.T. Accumulator.

solder. This is easily done, after a little practice, using a *large* soldering iron almost red-hot, with a pinch of powdered resin as a flux. If the amateur is doubtful of attempting this process he can use "plumber's" solder, this containing less tin than the ordinary "tinman's" or "soft" variety. In this case a coat of anti-sulphuric enamel should be applied to the connecting strips. The pairs of plates are now mounted in test-tubes 6 in. long by $\frac{3}{4}$ in. or $\frac{7}{8}$ in. diam. The tubes are supported in wooden racks, and the connecting lugs rest on the tops of the tubes, the plates hanging free within the

tubes. Narrow strips of perforated celluloid are passed down

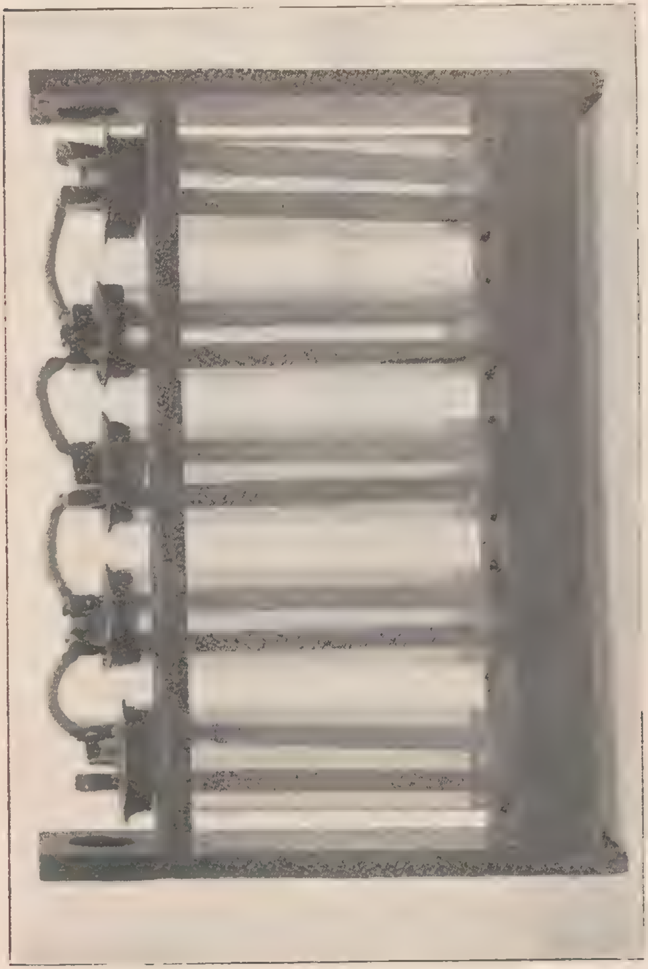

Fig. 106.—5-Cell Unit for H.T. Accumulator.

between the plates to prevent short-circuiting. Fig. 106 shows the original method used. Here the tubes are shorter,

and the plates are supported by celluloid feet at the bottom. The tops of the tubes, also, were sealed, suitable vents being provided. The later method is, however, a great improvement. The cells are joined in groups, the number of cells in each group being decided by the means available for charging. If the reader is blessed with a D.C. lighting supply the whole of the cells can be joined up in one group. Then charging is easily done by taking leads from a convenient lampholder, and putting the lamp itself in series with the cells. Care should be taken that the positive side of the mains is connected to the positive end of the battery, and a half-hour should give an ample charge, as the capacity of such small cells is somewhere about $\frac{1}{8}$ amp. Those who have no D.C. supply of sufficient voltage, or an A.C. supply, can adopt one of two methods: (1) charge from large-capacity accumulators, such as are used for filament lighting; or (2) charge from the A.C. mains, using a chemical or mechanical rectifier. These devices have been described very thoroughly in back numbers of the *Model Engineer*, and are well worth the amateur's attention. The writer does all his own charging by a chemical rectifier, with entire satisfaction. Now the voltage of the large-capacity accumulator will decide the number of small cells forming the groups mentioned above. When the writer made his first battery, six cells of 60 amp.-hr. capacity were available, so the small cells were arranged in groups of five, for it must always be remembered that the charging current must be in excess of that of the cells being charged —20 to 25 per cent. being most suitable. Leads from these groups of five were taken to a series-parallel switch, which is illustrated in fig. 107. Tracing out the wiring of this switch, it will be seen that in the charge position the cells, thirty-five in number, are placed in seven groups of five, the seven groups being in parallel, so that the battery then becomes one of 10 volts at about 1 amp.-hr. capacity. Upon charging being complete, the switch is placed in the discharge (or series) position, and the groups are then put in series, the battery becoming one with a voltage of 70 and of correspondingly lower capacity. Such a switch is easily made, and fig. 108 should be almost self-explanatory. The barrel is a piece of ebonite or fibre rod, provided with a spindle at either end. The spindle must not be continuous through the length of the rod, however. On opposite sides of the rod, plates of copper or brass are fixed,

and half-way between these plates, stout pins of hard copper or brass pass right through, their ends projecting to a length

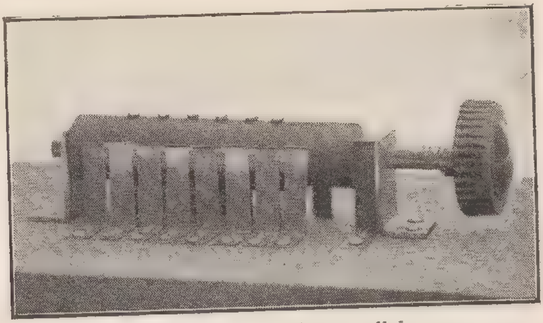

FIG. 107.—Series-parallel.

equal to the thickness of the plates. A series of hard brass or copper springs is arranged to press on either side, and the whole switch wired up as in fig. 109. The number of pins in the

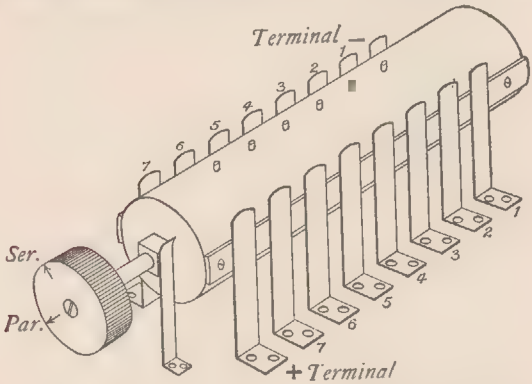

FIG. 108.—Details of Series-parallel Switch.

rod, and of springs on either side will, of course, depend on the number of groups of cells it is decided to form, as such a switch will deal with any combination the maker considers most suitable. Tappings from various points in the battery may be taken if it is thought desirable to use less than the

total voltage at any time, and there is no reason why the battery should not be made larger or smaller than that under discussion. Such an equipment will, with due care, give every satisfaction, and a long life before renewal is necessary. One or two remarks on essential points may be useful. First, use nothing but *pure* acid, and that of the correct specific gravity (1·2): failing other sources, any chemist will supply this; second, *never* short-circuit the cells, for they should not be discharged at a greater rate than about 0·04 amp.; third, never let them stand for any length of time in a discharged condition. It may be objected by some that such cells are not portable. They will, however, stand steady

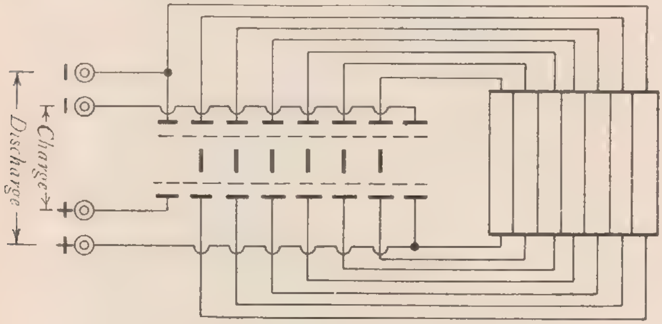

FIG. 109.—Wiring for Series-parallel Switch.

carrying without spilling, as the level of the acid is some little distance down the tubes. The writer does not recommend the use of glass-wool or other methods to produce the "unspillable" accumulator. All these devices tend to produce that great evil known as "sulphating" in lead cells; and what is of more importance to the wireless worker, unspillable cells of such a type are not at all steady in action. It may be interesting to some to know that it appears quite feasible to use old negative plates in the construction of cells such as have just been described. When accumulators are thrown aside as being past use, the negative plates are often in very fair condition. These may be cut up and half of the quantity formed into positives. The writer has not done this himself, but has seen a set where the procedure had been adopted, and apparently with complete success.

To sum up then, the really enthusiastic worker can do a great deal to make the source of H.T. to his apparatus an item of interest and pleasure. He can also ensure a decided economy by studying the question a little closer, and be free from those vexatious delays owing to temporary failure of the H.T. battery.

CHAPTER XI

SOME TYPES OF APPARATUS

THIS chapter is devoted to a fairly full description of some home-made pieces of wireless apparatus constructed by the author recently.

It is not by any means intended that they should be regarded as standards, or even as examples for copying; but rather to give the reader who contemplated constructing a part, at least, of his own apparatus a little idea of the methods adopted and the materials utilised. At the same time they will serve, to some extent, to exemplify the principles which have been briefly discussed in the preceding chapters.

The chief points to be observed in this branch of work are careful design, accurate and good workmanship, to ensure smooth working of all moving parts, good insulation throughout, and really good metallic contact in such portions as switches and wire leads to screws, etc. It is advisable, too, to let internal wiring be of ample section, and to avoid as far as possible crossing of leads; neglect of this precaution often leading to objectionable noises, or even a lowered efficiency from small capacity effects. The matter of finish will be one of individual concern and ability. Personally, the writer believes that if a piece of apparatus is worth constructing and gives good results, it deserves a good finish. Metal work should be lacquered, wood work should be polished or varnished, and ebonite should be brought to as good a surface as the skill of the worker will allow. Not only does the finished apparatus have a better and more pleasing appearance, but its efficiency will most likely remain constant over a longer period. As was stated in a previous chapter, dust and dirt are very detrimental to wireless apparatus. At the same time, the writer would far rather see a soundly constructed

piece of apparatus of poorer finish than one whose chief merit is ostentatious polish.

A Wavemeter.—The first piece to be described is a wave-

FIG. 110.—The Wavemeter in case.

meter. This is a piece of apparatus not often attempted by the amateur, because the great difficulty in its construction is undoubtedly the calibration. If a wavemeter to give approximate readings is all that is required, then the calibration can be done by simple calculations; but where the instrument is required to give pretty close readings, recourse must be

had to a standard instrument. That was the procedure adopted in the present case. The instrument illustrated is very compact, measuring about 6 in. by 5 in. by 8 in. over-all (fig. 110), and it is designed to measure wave-lengths of received oscillations, and also to transmit oscillations of a definite wave-length. The wiring diagram (fig. 111) will show how this is brought about, and indicates, also, the components of the instrument. These will now be described in order.

The Inductance.—This is a single-layer winding of No. 30 S.S.C. copper wire on a square-former of vulcanised fibre (fig. 112). The former is made from four strips 4 in. by 2 in. by $\frac{1}{8}$ in. screwed to stout internal angle pieces, a good dressing

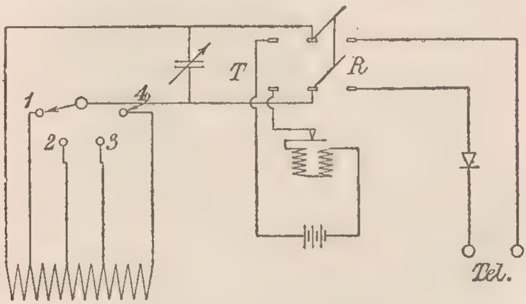

FIG. 111.—Wiring Diagram of the Wavemeter.

of old, sticky shellac varnish being used to act as a cement. The screws, ordinary wood screws, are of brass, and their heads are well sunk below the surface of the fibre to clear the windings. The corners of the former are nicely rounded to avoid any risk of cutting the wire. The wire has a total of 114 turns, and tappings are brought from Nos. 0, 14, 34, 66, and 114 to a four-point radial switch, so that four ranges of wave-lengths are available. This is a far better procedure than using a fixed inductance value, as in the latter case it is necessary to depend entirely upon the condenser for all adjustments.

This, while being rather more difficult, makes critical readings extremely difficult to obtain. As it is, each portion of the inductance has the whole of the condenser available to itself, with the result that the readings are much more open

and far easier to obtain. In this respect we depart from the general practice of using a condenser as sparingly as possible.

The Switch.—The switch needs little remark, except that it is designed to give certain contact and work very smoothly. The pressure on the switch-arm is mostly maintained by a spring washer, held in place on the underside of the spindle by a couple of lock-nuts.

The Condenser.—This is of exactly the same type as that

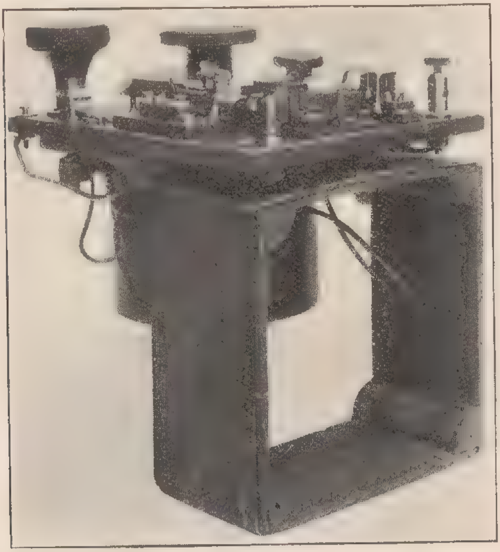

FIG. 112.—The Wavemeter removed from its case.

illustrated in fig. 17, in Chapter III., except that it has more vanes than the one shown there. There are ten movable vanes, each of $2\frac{1}{4}$ in. diam. The air-gap is $\frac{1}{64}$ in. and the metal (aluminium) about $\frac{1}{32}$ in. thick. The whole of the vanes are enclosed in a tightly-fitting cover to exclude dust. This cover must not, of course, be of metal, one being constructed of thin card and varnished serving quite well. The edge of the ebonite disc just under the controlling knob is divided on half its circumference into 180 divisions, and a small brass peg with a knife edge acts as an index.

The Change-over Switch.—This consists of an ebonite arm faced on two opposite sides with strips of thin copper. These are screwed on, great care being taken that the screws do not short-circuit the strips. At the lower end of each strip a small brass stud is fixed by gently riveting and sweating; and these, working in holes in small brass angle pieces, form the hinge. The contacts are pieces of phosphor-bronze foil soldered to stout brass angle pieces. The six angle pieces are secured to the ebonite baseboard by brass cheese-headed screws nutted below.

The Detector.—This is a carborundum-steel (exactly the same as shown at fig. 28, in Chapter IV.). The brass cup containing the carborundum crystal is screwed into a brass fitting secured to the base, so that replacements are easily made when desired. The steel blade (a piece of stout clock-spring) can be swung aside by loosening the rear screw, and its tension is adjusted by the ebonite-headed screw. For use in this case the detector is not supplied with current through a potentiometer, and works quite satisfactorily without.

The Buzzer.—This is a very tiny affair and apparently came from a dismantled Service tuner of some description. It is of the "Ericsson" type, and has been mounted on a substantial brass base. It was minus its armature blade and had been badly knocked about. The blade has been replaced by one cut from a very thin piece of clock-spring and is provided with a platinum contact. It now works exceedingly well, and is supplied with current from a pocket-lamp refill which is clamped in a little frame in the lid, connections being brought from this battery by flexible leads. The buzzer apparently requires very little current, as the battery lasts a long while. When nicely adjusted it gives out a tiny sort of squeak, and is quite free from the objectionable rasping buzz so frequently heard with tuning buzzers.

High-resistance telephones (3000 ohms) are used with the wavemeter, and a table (reproduced on p. 154) of its ranges is fixed within the lid.

Uses of a Wavemeter.—A wavemeter will serve many useful purposes. It is not intended to enumerate all these fully, and the reader desiring fuller information is referred to a good text-book, where he will find a full description of the methods employed. The following are some of the experiments most likely to be found useful:—

(1) To measure the natural wave-length of an aerial, join up the aerial and earth leads with the secondary of a small induction coil, putting a simple spark gap across the secondary terminals (fig. 113). A very small coil must be used, one giving $\frac{1}{8}$-in. spark being of ample power. One much larger is likely to interfere with any stations working within a fairly large area, as the arrangement is now a transmitting circuit ; very inefficient and crude, it is true, but one able to cause a good deal of annoyance. The wavemeter is best placed quite near the ground, and a single loop in the earth lead placed in inductive relation to the wavemeter will be sufficient for the purpose. The switch in the wavemeter will, of course, be placed to "Receive," and a pair of telephones connected to its terminals. Now, if the coil be worked intermittently adjustments with the wavemeter can be made until the loudest sounds are heard in the telephones. This will give the wave-length of the aerial. It may be difficult for one unaccustomed to this form of test to distinguish, nicely, the critical point, as the noise of the spark will probably be heard through the whole range of adjustments, but a little practice will soon enable the experimenter to judge the exact point. A simple oscillating circuit, such as that under consideration, does not give a well-peaked wave, this being the cause of the difficulty.

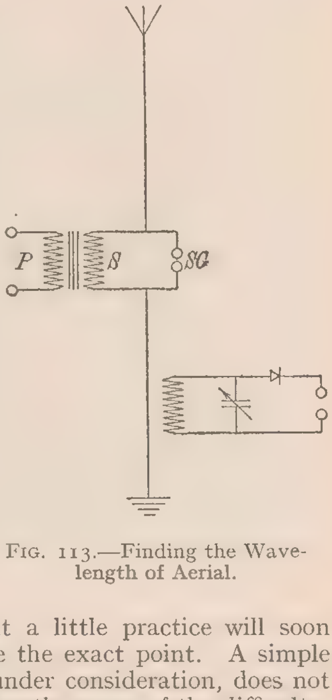

FIG. 113.—Finding the Wave-length of Aerial.

(2) To determine the natural wave-length of a closed oscillatory circuit. Any circuit of this description, *i.e.* one containing an inductance and a condenser can be so tested. Simply disconnect all subsidiary apparatus (detectors, etc.) from it and send feeble oscillatory discharges through by means of a buzzer. Place the wavemeter near the inductance portion of the circuit, and in inductive relation to it. Use

the wavemeter as a receiver, and the adjustment which produces loudest sounds in the telephones gives the wave-length of the circuit. Further experiments might include such determinations as :—The wave-length of a distant transmitting station; the wave-length of the various circuits in a receiver; the inductance of a coil and the capacity of a condenser. As before stated, a good text-book will explain these and several other interesting experiments.

The range of the wavemeter illustrated is not very great, as it was constructed for certain definite experiments. It could be increased by providing more inductance and a larger condenser. The inductance might take the form of separate coils of varying size, these being added as required. The instrument would then take somewhat the form of the Telefunken wavemeter. Missing figures in the table below could be added by interpolation from a curve plotted from the obtained results. If such curves be plotted it will be observed that the instrument is pretty true in its performance.

Condenser index.	Wave-length in metres.			
	Range 1.	Range 2.	Range 3.	Range 4.
6	260	—	—	—
18	—	350	—	—
20	—	—	600	—
30	—	—	650	—
36	—	400	—	—
38	—	—	700	—
40	280	—	—	800
44	—	—	750	—
50	—	450	800	—
60	—	—	850	—
65	—	—	—	1000
70	—	500	—	—
80	300	—	900	—
90	—	—	—	1200
96	—	550	—	—
130	320	—	—	—
140	—	—	1100	—
160	—	—	—	1500
170	340	—	—	—
180	350	—	1300	1700

It is perhaps necessary, in conclusion, to remark that such an instrument as that here described is not applicable to "C.W.," a special form known as a "Heterodyne" wave-meter being necessary in such cases.

A Valve Receiver.—As will be seen from figs. 114 and 115, this is a portable set, and can be used in conjunction with a low-frequency amplifier, when it is quite suitable for use with

FIG. 114.—The Complete Valve Receiving Set.

loop or frame aerials. The writer does not altogether favour portable sets, especially those of very small dimensions, and strongly advises those to whom space and other considerations are of little matter to make up a set of unit pieces of apparatus, wiring them up suitably and allowing plenty of room between each. This plan provides freedom for making up experimental circuits, and also does away with those troubles which can often be traced to inter-action between the components of the circuit. There are times, however, when a portable set is practically the only form that can be used, and it was

this consideration which caused the set under notice to be constructed. And before proceeding further, the writer would like to acknowledge his indebtedness to those friends who discussed with him the pros and cons when the set was being planned.

A glance at the diagram of connections (fig. 116) will show

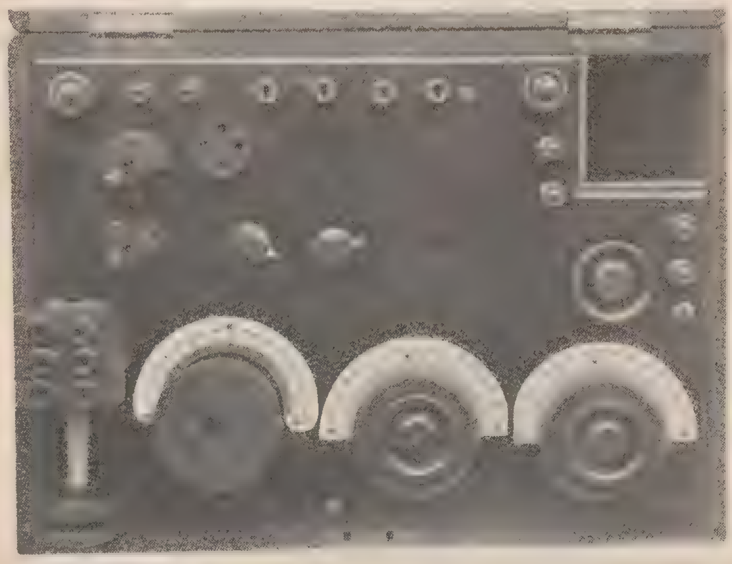

FIG. 115.—Plan of the Valve Receiving Set.

that the idea has been to make the set, as far as possible, of universal application. It can be used as a simple valve circuit, either with or without a leaky grid condenser; a closed circuit can be coupled to the aerial circuit; provision is made to allow, if necessary, exterior additions being added to the circuit; the telephone transformer can be cut out altogether, and is also arranged for using either high- or low-resistance telephone receivers. A further consideration is, that while a fairly skilled amateur can construct all the various portions for himself, each portion is of more or less standard

pattern, so that the amateur who has little mechanical ability may purchase the various items quite readily from any of the well-known dealers in wireless apparatus, and connect them up with the minimum of trouble.

The containing box was one which had held some scientific apparatus at one time, and as it was well made and in good condition, was put to its present use. The various partitions originally in it were carefully removed, the outside rubbed down with fine glass-paper and repolished. Its measurements inside are $12\frac{1}{2}$ in. by $8\frac{1}{2}$ in. by $5\frac{3}{4}$ in. deep, the lid being hollow. Originally, the hollow lid did not allow sufficient headroom above the baseboard on which the fittings are mounted.

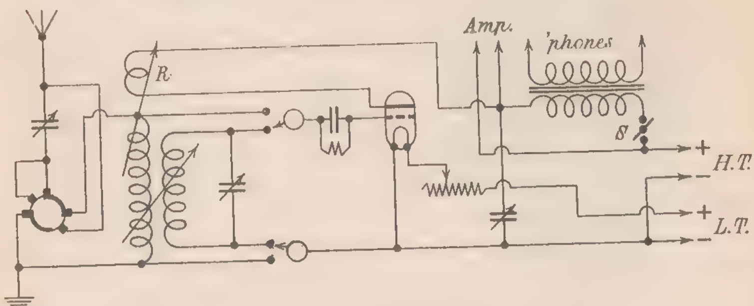

FIG. 116.—The Conections of the Portable Set. .

This was remedied by adding a mahogany extension $1\frac{1}{4}$ in. deep all round.

The Baseboard is a piece of very old, close-grained mahogany about $\frac{1}{2}$ in. thick, covered with a sheet of ebonite $\frac{1}{8}$ in. thick. This ebonite is not for show purposes. Every metal portion carrying current—down to the smallest screw, or finest wire—and attached to or passing through the baseboard is bushed with substantial ebonite tube, so that insulation is as good as can be obtained. This method is far cheaper than using an all-ebonite base, because one to suit the dimensions given would have to be at least $\frac{3}{8}$ in. thick. The writer has advocated this method in the *Model Engineer*, and one correspondent of that journal took him to task over the question, stating that, in his opinion, there was no need to use ebonite at all. The writer takes leave, however, to adhere to his own opinion, and that is that ebonite should be used wherever possible ;

and can call to mind a set, well made in every respect, where results were greatly improved by substituting an ebonite base for the original waxed wooden base. A thin sur-base on a good foundation with ebonite bushing for all holes may sound a fiddling sort of job, perhaps, but it is certainly economical, and gives every satisfaction. To return : the base rests on a substantial ledge running round the inside of the box, and is fastened at the ends by extra broad-headed screws to aluminium angle pieces. Everything is attached to the underside of the base, so that by removing these two screws the whole concern lifts out bodily. This is a very convenient arrangement, as fitting up can be done in comfort, all wiring properly arranged (an important item), and yet even the smallest detail is readily accessible and quite rigid. This method of fitting also prevents the accumulation of dust on the various portions, and it must be remembered that dust is a most insidious evil where wireless apparatus is concerned. At one corner a square pocket is arranged, and this, well lined with thick felt, carries the valve when the set is out of use. It might be mentioned here, in passing, that all the ebonite is rubbed down to a matt finish with finest pumice-powder and water. Matt-finished ebonite resists the action of the air for a much longer period than the highly polished article, and does not seem to attract dust particles quite so readily.

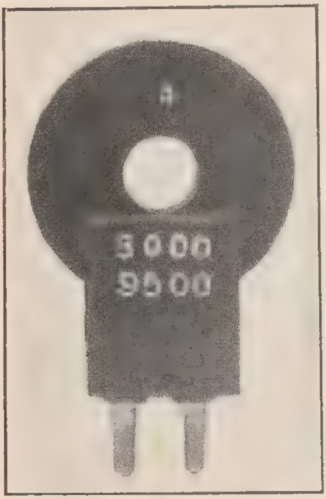

FIG. 117.—An Inductance Spool.

The Inductances are of the slab variety, similar to those sets advertised so widely. For the benefit of the beginner it should be explained that such inductances have a fixed value, largely depending upon the number of turns of wire in them. Their values overlap each other a little, so that if it is desired to receive signals from stations working on a certain wave-length, then the inductance covering that wave-

length is selected. The inductance, being of definite proportions, needs no adjustment when in use, and the removal of even one adjustment from a set is an advantage. The inductances, eight in number, were wound on ebonite spools turned up from pieces of sheet of suitable thickness; the wire, No. 36 D.S.C. (or enamelled), being passed through a bath of wax during winding. They are thus very strong and can be handled with perfect safety; insulation being also of the best. Each spool is marked with its number and the range of wave-length for which it is suitable. Each is fitted with an ebonite extension, the ends of the wire being brought to brass plugs fitted on the lower edge of the extension. These ebonite extensions vary in length, according to the length of the spool, so that when placed in position for use they are concentric (fig. 117). Particulars of the slabs are given in the following table:—

No. of slab.	Turns of wire.	Dimensions of winding space.			Wave-length range with 0·0016 mfd. condenser.	
		Outer diam.	Inner diam.	Width.	In series.	In parallel.
0	90	2″	$1\frac{3}{4}$″	$\frac{3}{32}$″	500— 900	1,100— 2,300
1	100	,,	,,	,,	600— 1,050	1,200— 2,500
2	180	$2\frac{1}{16}$″	,,	,,	1,300— 1,700	2,000— 4,200
3	280	$2\frac{1}{8}$″	,,	$\frac{1}{8}$″	1,600— 2,300	2,800— 6,000
4	440	$2\frac{1}{2}$″	,,	,,	3,000— 3,800	4,500— 9,500
5	830	3″	,,	,,	5,000— 7,000	7,500—16,000
6	1500	$3\frac{3}{8}$″	,,	,,	8,000—12,000	15,000—28,000
7	1935	$3\frac{1}{4}$″	,,	$\frac{1}{4}$″	unmeasured.	

In addition to the above slabs it is proposed to make up another, somewhat smaller than No. 0, which will in certain cases be used as the reaction coil. A friend who kindly subjected the completed slabs to critical tests, reported very favourably as to their behaviour. He says he obtained very clear signals with them, much clearer in fact than when using

a professionally-made set of slabs he possesses; and he attributes this to the fact that insulation has been reduced to the minimum; in other words, the coils of wire are as close to one another as it is possible to get them. And in connection with these slabs, the writer would like to mention what he believes to be a discovery. No new development in wireless, it is true, but one which may be of interest to many amateur mechanics. In common with many others, no doubt, the writer has often wished for a satisfactory adhesive or cement for ebonite. When the slabs were in course of construction, the problem of how to fasten the extensions to the spools presented itself. It was at first proposed to rivet them together, but the experiment was tried of cementing them, using "Croid" glue. Entire success resulted, and the writer is only too pleased to acknowledge the merits of this fine adhesive. The surfaces to be united should be roughed with fairly coarse emery-cloth and be absolutely free from any trace of oil or grease, and the joint should be put under moderate pressure. It is not claimed that the joint will stand very great strains, but for all ordinary purposes it would seem to be quite satisfactory.

The Inductance Holder.—The sockets receiving the plugs on the extensions of the inductances are mounted in ebonite blocks, which form a separate unit on the baseboard. The centre block is fixed, the others moving in a radial direction on a stout tubular spindle passing through it. The requisite stiffness of movement is obtained by placing a spring washer between the two ebonite handles. These handles are placed some considerable distance away from the holders so that capacity effects, due to the presence of the hand when making an adjustment, are cut down as far as possible. Well-insulated flexible leads pass from the sockets through holes in the baseboard. Figs. 118 and 119 give a closer view and detailed drawing of the whole arrangement respectively. The inductance in the centre fixed socket forms the aerial inductance, that at the rear the closed circuit inductance, while the one at the front forms the reactance. When the receiver is out of use the set of inductances is carried in a separate box. The plugs on the spools and the sockets are, of course, accurately spaced, so that all are interchangeable. Slab No. 7 is really additional to the set of slabs, as it can be used as the closed circuit inductance when No. 6 forms the aerial induct-

ance. It will be found, as a general rule, that the closed circuit inductance is best when a little larger than that in the aerial circuit. No. 0 is generally used as the reactance.

The Condensers, three in number, are all variable. That for the aerial circuit is of the Marconi type, with double banks of vanes and ebonite dielectric. Its total capacity is 0·004 mfd. This is rather large, no doubt, but it had been constructed for another purpose, and was further utilised in the set to avoid the construction of another. It is hoped, later on, to replace it by a condenser of the ordinary air dielectric type of about 0·0015 mfd. capacity. The condensers in the closed and telephone circuits are of the ordinary type, each

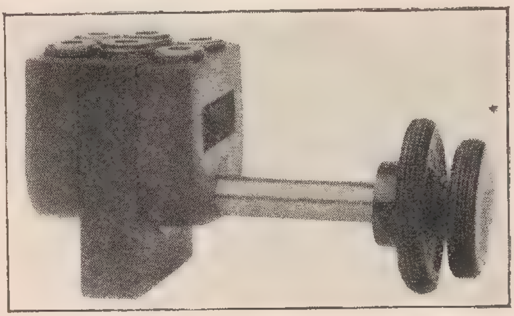

FIG. 118.—The Inductance Holder.

with a maximum capacity of 0·0004 mfd. It is not general to have a variable condenser in the telephone and H.T. circuit, but the writer can vouch for it as being a valuable feature and much to be recommended.

The Transformer is entirely home-made, and has the unusual feature of possessing two entirely distinct secondary windings. This was done by way of experiment, the idea being that either high- or low-resistance 'phones might be used. It might be argued that the same result could have been obtained by using one winding and bringing out a tapping at a certain number of turns, the resistance of which would be suitable for the low-resistance 'phones, and using the whole of the winding for the high. This is true enough ; but what would be the result were it necessary to use *both* pairs of 'phones at the same time ? The writer does not favour the use of

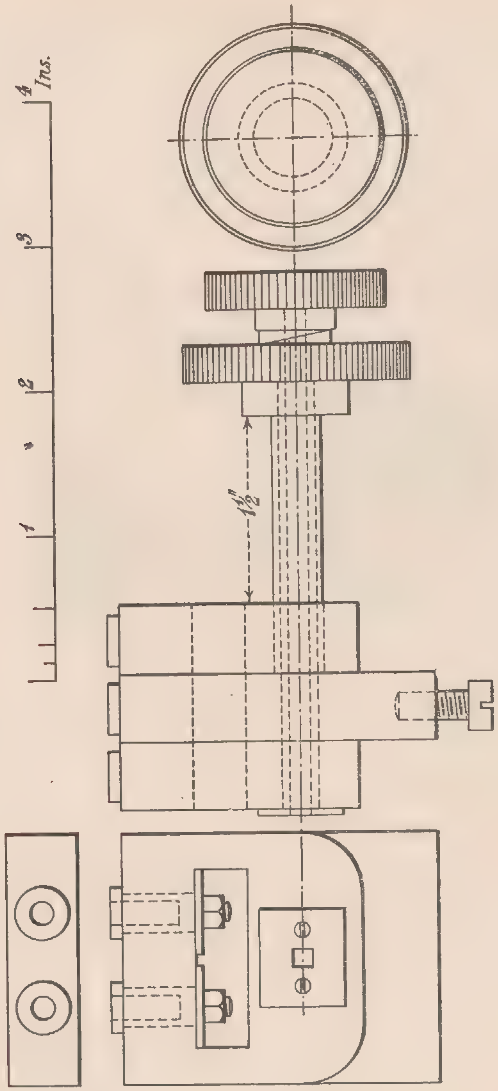

FIG. 119.—General Arrangement of Inductance Holder.

'phones direct in the H.T. circuit, but as it was desired to use some high-resistance instruments, provision had to be made. To some it may seem superfluous to use a transformer at all; but, as was pointed out in an earlier chapter, the use of a transformer is very advisable, because, as a steady current is not reproduced in a transformer, the telephone receivers are relieved from being continually in circuit, with consequent gain to insulation and the polarity of their magnets. The magnetic circuit of the transformer is of thin Stalloy iron, with sandwich joints clamped up tightly with substantial bolts and nuts. The strips of iron are varnished on one side to prevent formation of eddy currents. The primary and high-resistance

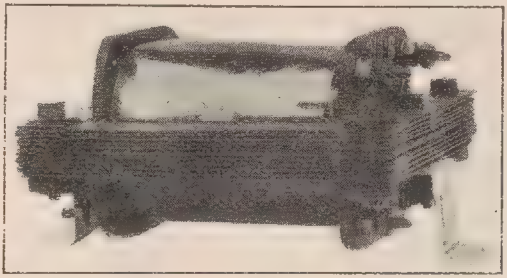

Fig. 120.—The Transformer.

secondary windings are of No. 44 S.S.C. wire, 2 oz. being used for each. The low-resistance secondary is of No. 40 S.S.C., about 100 yards being used. Resistances of windings are (approximately) primary and high-resistance secondary, 4000 ohms each; low-resistance secondary, 130 ohms. Insulation was carefully attended to at every point. The transformer is very quiet in action, and has well repaid the time spent upon it. A switch is provided, so that it may be cut out if desired. This is useful when using the receiver in conjunction with an amplifier, as many of these instruments are fitted with a line-to-valve transformer. When the transformer is "out," a pair of 'phones connected to the terminals marked "amplifier" will be directly in the H.T. circuit (fig. 120).

The Series-parallel Switch for the aerial condenser is of the barrel type, as this form is quicker in action than the throw-

over pattern, and, moreover, could be mounted below the baseboard. It is shown separately in fig. 121, while a detailed drawing of it is given in fig. 122, where, however, some few details have been omitted for the sake of clearness. The barrel is a piece of ebonite rod on which a brass ring is mounted, this being secured by eight small brass counter-sunk head screws. It was then slit into four equal portions. Against these four metal sections press the ends of five phosphor-bronze springs, so disposed as to produce the desired connections. By this method the copper ends of the fingers never leave the surface of the brass, so that a very smooth action is secured, and the contact, being a rubbing one, is always certain. The bronze fingers are mounted on a larger piece of ebonite rod, which also forms the bearing for the central spindle. A sector-shaped piece of thin brass mounted on the ebonite barrel is so shaped as to serve as a stop for limiting the amount of rotation of the barrel. It has a radius considerably more than that of the barrel, so that its edges will come against the upright members of the supporting frame. An exactly similar switch, but with six fingers instead of five, is provided to put the closed circuit in or out of action.

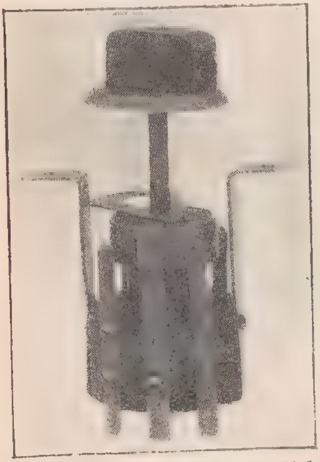

Fig. 121.—The Series-parallel Switch.

The Filament Rheostat calls for no special remark, being of the usual circular type and wound with Eureka wire (bare) on a threaded piece of celluloid rod. One end of the resistance wire is soldered to a piece of bare copper wire of the same gauge, so that the radial contact arm makes contact with the copper instead of the Eureka when in the "out" position, the filament then receiving full current should this be necessary.

The Grid Condenser and its *Leak* were purchased ready-made from an advertiser in the *Model Engineer*. They bear the mark "R.E.F." and came from some form of ex-service apparatus.

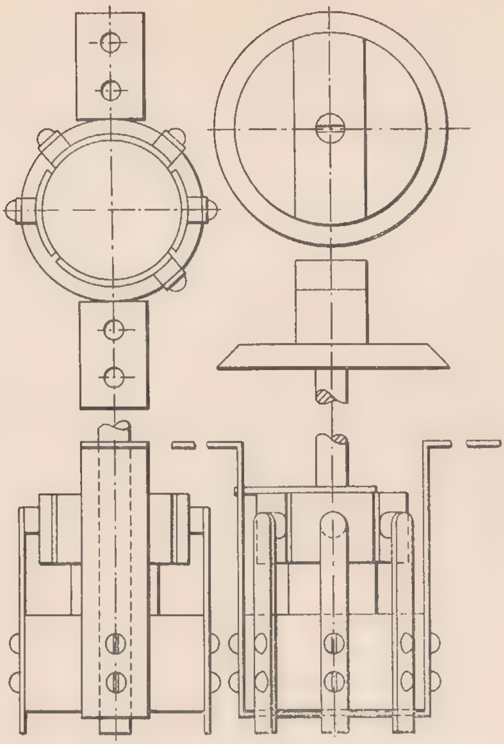

FIG. 122.—Elevations and Plans of Series-parallel Switch for the Aerial Condenser.

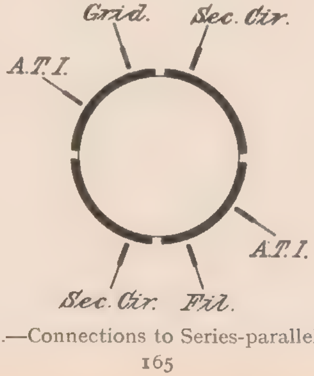

FIG. 123.—Connections to Series-parallel Switch.

The valve holder was also purchased, and is of the squat type with legs projecting well below its under surface. The two switches which cut out the grid condenser and the transformer, respectively, are of very simple construction and need no comment. All switch handles, terminals, etc., are now provided with tablets showing their position or purpose, though the photographs were taken before these were affixed. A key plan of the baseboard is given in fig. 124. All connections are in No. 24 enamelled wire carried in insulating tubing, except those from the inductance holders, which are of well-insulated flex. The various connections are well spaced to minimise capacity effects as far as possible, and this is a point which should always receive careful attention.

A Three-valve Amplifier.—Like the receiver this is a portable and self-contained instrument, and is the outcome of an attempt to obtain in one piece of apparatus as many conveniences as possible with the minimum of complexity. No new principles are to be found in the design, nor is anything very wonderful claimed for it. The valves are coupled by transformers, and the following are its chief features:—By the simple movement of a switch, either one, two, or three valves may be used, and this switch controls not only the connections between the valves, but also the filament current to each. Each valve is provided with a separate rheostat for its filament, a feature which, in the writer's opinion, is a valuable one, as it is always possible under such circumstances to get the utmost out of each valve. In spite of the fact that valves of any one type are now almost standardised in design, there must exist small differences in their behaviour, and although they will give satisfaction when worked within fairly wide fixed limits of adjustment, it is always preferable to use them on the one most critical adjustment, and this point will vary slightly with each individual valve. Another feature, not often adopted by amateurs, is that provided by the switch AR (fig. 125). In one position this switch will cause the instrument to act as a detector-amplifier, while in the other it is an amplifier only. A study of the diagram of connections will explain how these operations are brought about. In the first position a leaky grid condenser is included in the circuit, so that the first valve acts as a detector, the other two being relays of the rectified current. In the other position this leaky condenser is put out of action, and all three

valves act as amplifiers. This switch is of the rotary pattern, exactly similar to those included in the description of the valve receiver. The primary of the first transformer is provided

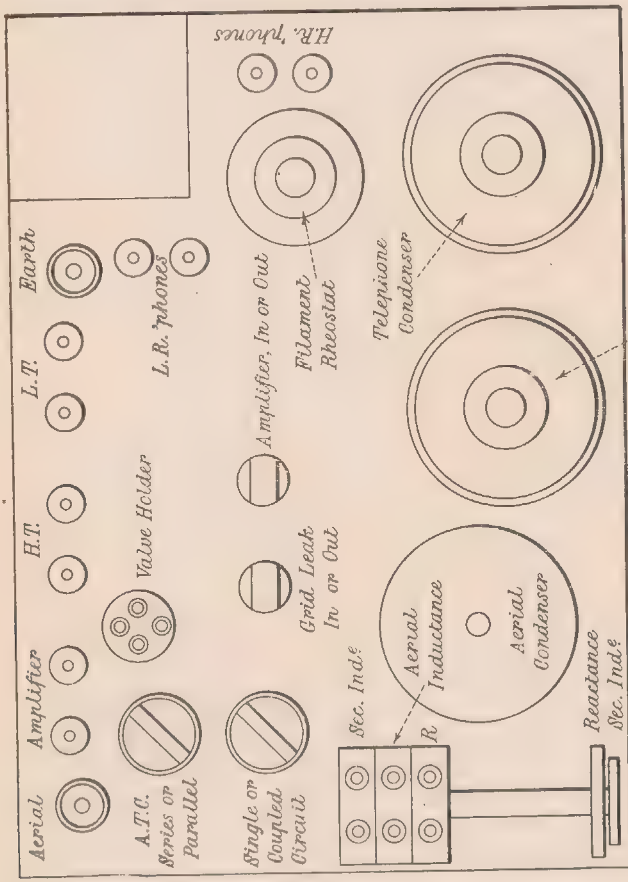

FIG. 124.—A Key Plan to the Baseboard.

with five tappings, which are brought to a selector switch S1 (fig. 125). This is also a useful feature, as the primary can be brought to a value where its impedance is about equal to that of the external circuits connected to the instrument. It was mentioned that either one, two, or three valves could

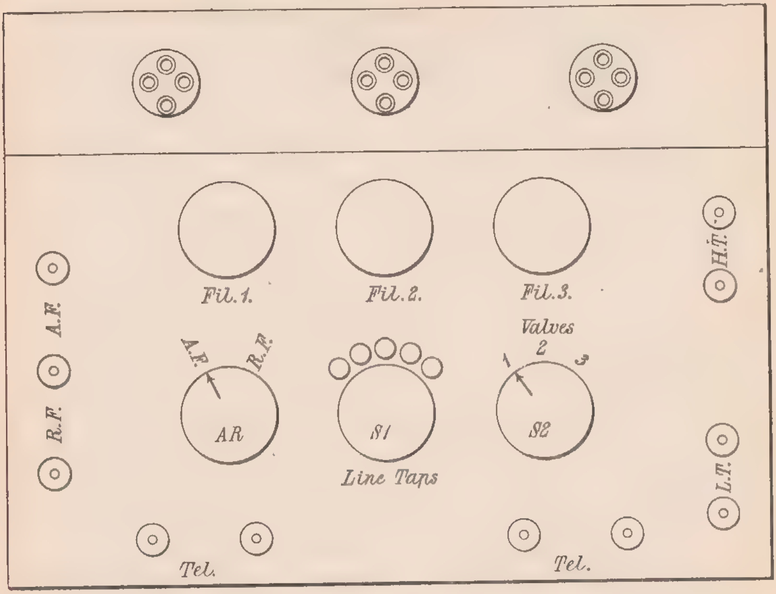

FIG. 125.—Key Plan of Amplifier Base.

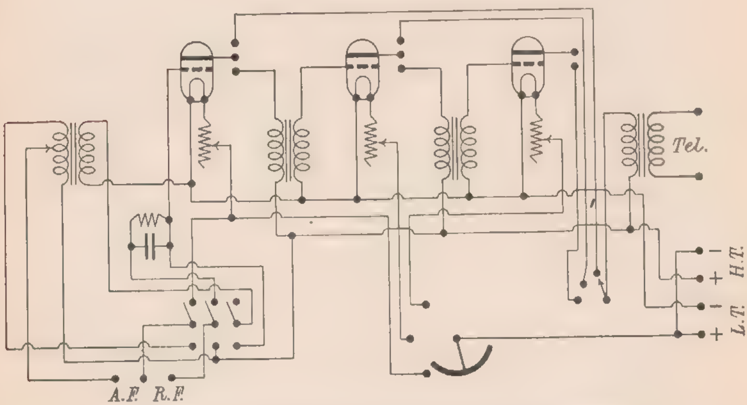

FIG. 126.—Wiring Diagram of Three-valve Amplifier.

be used as desired. This selection is possible by the use of switch S2. Many amateurs, especially those who make up circuits from unit pieces of apparatus arranged on a panel or bench, arrange to provide amplification in stages by selection, but the operation of selecting is not usually so simple as it might be. A common method is to use a plug and jack, somewhat similar to those used on telephone switchboards. Even then it does not seem possible to carry out all the operations required by means of plugs and jacks alone, that is, in one movement alone, at any rate. The writer has devised

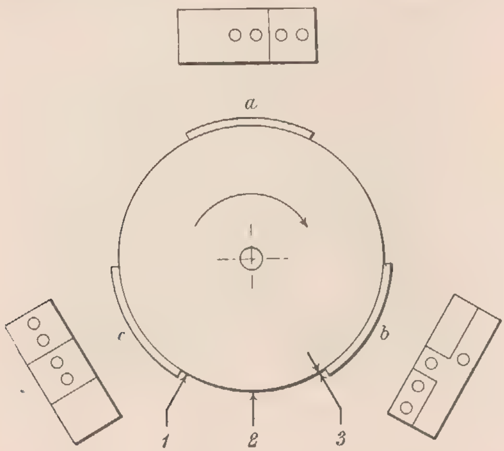

FIG. 127.—Diagram of Selection Switch.

a rotary switch which will carry out the matter quite satisfactorily, and obviates any mistake or wrong connection (fig. 127). Although at first sight it may, perhaps, seem a little complicated, its action is really quite simple. Reference to fig. 127 will explain more clearly. Here it is shown in three separate sections, each having a definite function. A disc of ebonite, mounted on a spindle, carries on its circumferential face a strip of brass, which is divided into three main portions. Each portion is subdivided according to the function it has to perform, and has pressing against it the soft copper ends—or fingers—of certain phosphor-bronze springs. In *a* the section is quite plain and always in contact with finger L.T.+. As the switch is rotated through the three positions,

the fingers connected to the filaments of the first, second, and third valves respectively are brought into contact one after the other, and remain in contact, thus placing all the filaments, eventually, in parallel across the L.T. battery. In *b* the section is L-shaped and always in contact with the primary of the valve-to-'phone transformer. In position 1 the plate of the first valve is in contact also; but as positions 2 and 3 are reached, the plates of the first, or first and second, valves are cut out in turn, finally leaving that of the third valve

FIG. 128.—The Completed Amplifier.

in contact only. In *c* the section is reduced to two small pieces which are inoperative in the first position, but in the second and third connect the plate of one valve (inductively) to the grid of the next, through an intervalve transformer. Thus, rotation of the disc one step at a time—and the amount of rotation for each step is only about $\frac{1}{2}$ in.—performs three operations. A spring-controlled roller, falling between the notches on a quadrant-shaped piece of brass mounted on the spindle, forms a locating and locking device. Though in the above description it has been stated that the fingers in some positions do not make contact with the brass strip, it must not be supposed that they then come forward and touch the ebonite. This, even if arranged for, would give a very jerky

movement. In the no-contact position the fingers still rest on brass portions, but these are very carefully insulated by fine slits from those intended to provide contact. The whole arrangement works with delightful smoothness, and, as the contacts are rubbing ones, good electrical continuity is assured.

Of the transformers, four in number, three are of the usual Service pattern and were purchased. The first, or line-to-'phone, has already been mentioned. The second and third, or intervalve, need no comment. The fourth, or valve-to-

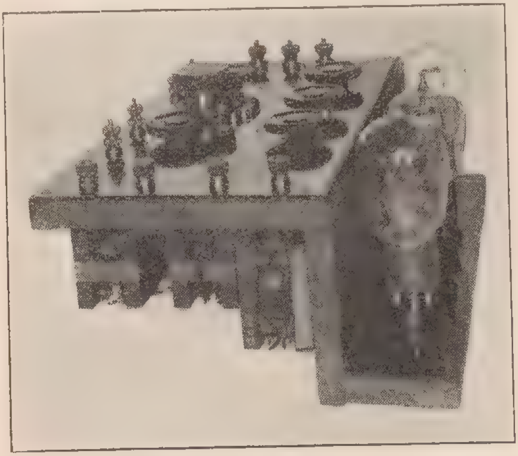

FIG. 129.—The Amplifier removed from its case.

'phone, is home-made, being of similar design to that described in connection with the valve receiver, except that it has one secondary winding only. Its primary and secondary are in the ratio of 25 to 1, so that the use of low-resistance 'phones only is indicated. However, should any one desire to use high-resistance 'phones, and the writer's opinion on this point is given earlier, a pair of terminals is provided for the purpose. The filament rheostats are of the sliding-contact type, the sliders being moved by the rotation of quick-feed screws. The valve holders were also purchased, and are of quite ordinary design. As in the case of the valve receiver, all fittings are mounted on thin ebonite ($\frac{1}{8}$ in. thick) screwed down to $\frac{1}{2}$-in. mahogany; all wires or screws carrying current and passing

through the wood being bushed with ebonite tube. This composite base, if it can be rightly called a base, is fitted in a mahogany box, which was at one time a portable medical chest. The valves are located in a sort of well at the back, this extending the full depth of the box. The remaining portion is occupied to a depth of about $1\frac{1}{4}$ in. by a drawer which is very useful for holding flexible leads, etc. Originally this drawer extended from front to back completely, but as there was not then sufficient depth for the valves, it has been shortened to the extent required. The whole instrument has quite a good appearance and performs well ; in fact, three valves are rarely used (figs. 128 and 129).

High-frequency Transformer.—This is a very useful accessory to the wireless experimenter's equipment, and is best produced as a separate unit, which may be coupled up in a receiving circuit as required. It is not at all a difficult piece of apparatus to construct, and many designs have appeared of late. The one illustrated here is of quite ordinary form, but is so arranged that it may be used as an inductance, for which purpose it is very useful in certain forms of circuit.

As a transformer it is used to enhance the value of very weak signals before they are rectified by a valve. This method is rather to be preferred than attempting to amplify by means of one or more valves later. It differs very considerably from the ordinary type of transformer, in that it has no iron core to form a magnetic circuit. This is because oscillatory currents of high frequency reverse their polarity far too rapidly for the molecules of the iron to respond to the building up, breaking down, and rebuilding in the opposite sense of the magnetic fields produced. Indeed, the presence of iron would be highly detrimental, if not fatal, to the correct functioning of such a transformer, which, as a matter of fact, would then be simply a choking coil. Such conditions, then, require that the turns of wire shall be as close to one another as is possible consistent with proper insulation ; and, on the other hand, the turns must not be too numerous or excessive damping from self-induction will occur.

In the transformer illustrated there are ten separate coils of wire, each composed of 480 turns of No. 40 S.S.C. copper wire. The coils were wound in a brass-former made up of two discs separated by a smaller one, the three being bolted tightly together (fig. 130). The larger brass discs must be of stout

metal, as it will be found that there is a marked tendency for the coils of wire to force them apart during winding. The writer used hard brass of No. 14 gauge. Such a coil-former is a very useful article to the amateur who does much experimental work, as by its aid coils of good shape and of a great variety of dimensions can be turned out quickly, comfortably, and with the certainty that they are, if desired, of uniform value within very close limits. The outer flanges might be, say, $4\frac{1}{2}$ in. diam., as coils are rarely required of greater diameter than those used in the transformer under notice. A saw-slit from the edge to within $1\frac{1}{2}$ in. or so of the centre will enable one to observe that the requisite depth of

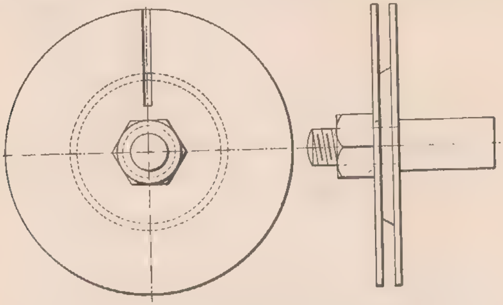

FIG. 130.—Former of Slab Coils (half-size).

winding has been reached. The smaller separating disc must be of diameter equal to the inner diameter of the required coil, and of thickness equal to that desired in the finished coil. It should be tapered slightly, in order that it may be withdrawn from the completed coil without disturbing the inner turns of wire. A variety of these inner discs could be constructed and used as occasion demands. The wire should be run through a bath of melted wax and from this direct into the former. A little wad of cotton-waste held between the finger and thumb will wipe off all surplus wax, while at the same time a fair tension can be kept on the wire. Coils made in this way will be found to be surprisingly strong, though they should be handled with due care until they are finally assembled in place. Should it be necessary to produce coils of still greater robustness, the former, with the wire still within it, can be immersed bodily in a bath of melted wax, which

is maintained at a temperature just a little below its boiling point, and allowed to remain there until no bubbles arise from it. If it is then withdrawn and allowed to cool, the flanges may be removed by gently warming them and cautiously insinuating the blade of a thin palette knife between them and the coil. This method produces a coil which is a solid hard block; so solid that it will give out quite a ring if gently struck.

The dimensions of the coils in question are 3 in. outer and $1\frac{1}{2}$ in. inner diam., respectively, and $\frac{1}{6}$ in. thick. They should all be wound in the same direction, and the finishing end of each carefully marked. The finished coils are mounted on a short length of ebonite tube and separated from each other by a waxed paper disc. The writer uses thick, close-textured filter paper for such discs, but they should be well examined to ensure they are free from pin-holes or unwaxed places. The end coils are faced with ebonite cheeks $\frac{1}{8}$ in. thick, and then the whole set of coils should be pressed up together with a fair amount of pressure. This can be done by putting a thread on the ends of the ebonite tube and then putting on a couple of metal rings (not iron or steel) screwed to suit. If this cannot be managed, a piece of stout ebonite rod screwed at each end may be passed right through the tube, held concentrically by a couple of ebonite washers, and the requisite pressure applied by wide hexagon nuts at either end. These nuts may also hold in place a pair of L-shaped pieces of metal which will form the supports for the set of coils. The former method is perhaps the better, as an iron core can at any time be passed through the centre tube if desired. At any rate,

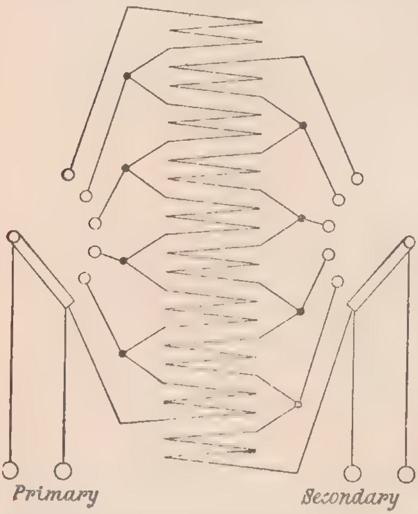

FIG. 131.—Connections of H.F. Transformer.

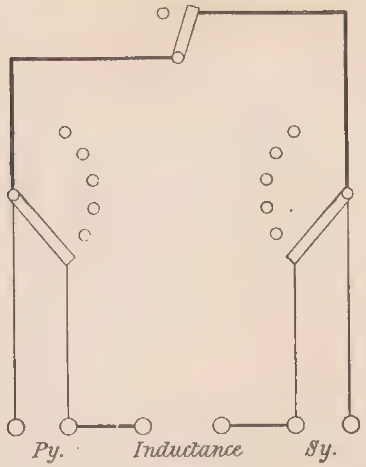

FIG. 132.—H.F. Transformer as Tapped Inductance.

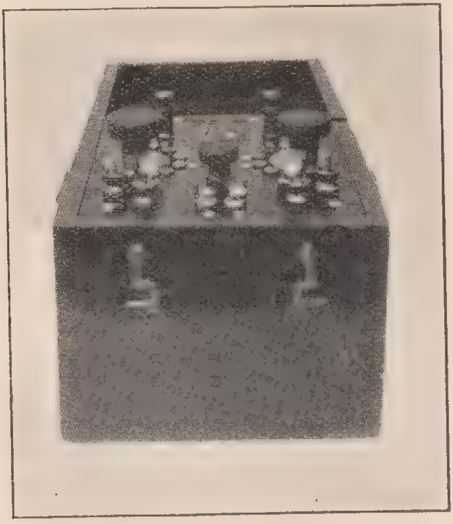

FIG. 133.—The Transformer complete.

for high-frequency work no iron must enter into the construction, and it is as well to let no metal at all pass through the tube.

Two six-point radial switches are mounted on the baseboard and connected up, as shown in fig. 131. It will be seen that alternate coils are connected together, and great care should be observed that no coil is connected in a reverse direction to any other. If all have been wound in the same direction and are all placed the right way up, then the outer end of one connected to the inner end of the next will put matters right. Leads from the points of connection are taken to the switches as shown. This method of connection enables the ratio between primary and secondary to be varied at will.

To arrange for the transformer to be used as a tapped inductance, another pair of terminals and a small two-point switch should be provided, and further connections made as in fig. 132, where the previous connections from the coils have been omitted. It will be seen, now, that the radial switch-arms can be connected, and that by moving them forward one point at a time, alternately, any number of coils from one to ten can be put into circuit, and all acting inductively. The ebonite base to which all the portions are fixed can be made to form the inner lid of a small box, and a compact and handy piece of apparatus is produced (fig. 133).

CHAPTER XII

EARTH SIGNALLING, OR "T.P.S."

To some it may seem that the subject here discussed is a little out of place, and hardly comes, legitimately, within the scope of wireless signalling, while to others it may be something quite new.

Now earth signalling, or "T.P.S." (*telegraphie par le sol*) as our French friends call it, was very largely developed during the Great War, being very much used on both sides. The French especially took up the matter very seriously, and some very clever apparatus was designed for use in this branch of signalling alone. Indeed, it might almost be said that the present-day amplifiers owe their being largely to this fact.

As many readers may be aware, telegraphy and telephony

play an extremely important part in warfare, and those who have had no opportunity of actual experience in such work would be amazed at the ingenuity and complexity of the systems employed in the Signal Service. Now, it must be quite evident that war conditions do not always permit of very precise and careful workmanship in the matter of lines for telegraphy and telephony. Often communication has to be established with great rapidity and under very trying conditions. Even when communication has been accomplished successfully the lines are liable to disturbance from a variety of causes. Leakage, either partial or complete, is therefore quite common, and it was early discovered that such leakages could often be "tapped" quite effectually. And the tapped leakages were, as often as not, from the lines of foe as well as friend. Often, too, signals were deliberately "put to earth" when it was not possible to construct even a temporary line; and during that period when the warfare was largely a matter of trench work this was frequently the case.

Then, again, profiting by what is quite a common experience in ordinary telegraph and telephone practice, viz. disturbance by induction effects, efforts were very frequently made to "overhear"—for "tap" is hardly the correct term to use—signals passing along a line which did not leak.

So that, summarising, it may be said that messages can be transmitted and received, the earth acting as medium, either by conduction or induction, and that the transmission may be accidental or deliberate. It will be fairly evident that the currents to be detected are not likely to be very strong in any case, so that sensitive apparatus is necessary for their reception. The currents, too, are of low frequency, and, with the exception of those deliberately put to earth, of audible frequency. A single-valve amplifier will generally be sufficient for the purpose, though two, three, or more valves in cascade were often used.

Now, let us consider the matter, briefly, from a theoretical point of view. Suppose we have two stations A and B (fig. 134) connected by telephone, and that an earth return is used. Or, alternatively, let us suppose points A and B represent spots where one wire of a metallic circuit leaks, then there will be currents passing in the earth between these two points. The currents will tend to spread out in various directions, this largely depending upon the earth resistance; and it should be

evident that the spreading out will be more likely to be greater with an earth circuit than with a leaky metallic return, because the currents going to earth will be stronger. These spreading paths are represented in the figure by dotted curves. Now, suppose that at two points in a line approximately parallel to the telephone circuit, and marked C and D in the figure, we drive metal pins into, or bury metal plates in, the earth and bring leads from these to some detecting apparatus, R. Then, between points C and D there will be a difference of potential, and current will flow through R. This will be due entirely to conduction, but it is conceivable that, should the currents be fairly strong, magnetic strains will be set up, and that these in turn will induce currents in the wires leading

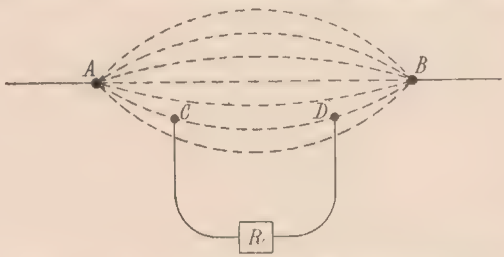

FIG. 134.—Diagram showing Method of Tapping Earth Conduction.

to R, so that it is often the case that interception is due both to conduction and induction.

Suppose, instead, that the earth-pins, or plates, were placed at points C and D, as shown in fig. 135. Theoretically, these points are at spots of equal potential, so that no current would flow through R, and it would be necessary to move one or both of the pins to fresh positions, say, C to C′, until a difference of potential was obtained.

Now, it may be interesting to consider the question of the range over which such "tapping" or interception can take place. There are, of course, two factors to be taken into account: (*a*) the resistance of the earth through which the currents are passing, and (*b*) the strength of the currents going to earth. This is supposing that the earth base in use is the best possible. Many persons would suppose that the damper the soil the better would be the result. This is far from being a fact in many cases. It must not be forgotten

that soil is not of the same substance over wide areas or for different depths. Consequently, if the currents are passing through a fairly thick layer of relatively good conductivity, there will be little tendency for them to spread out far, so that the possible range is likely to be very restricted. On the other hand, a thin layer of soil of fair conductivity lying on a layer of rock will, in all probability, permit of much greater ranges, because the available path for the current being so restricted will cause it to spread out to a much greater degree. It is easy to see, too, that if the earth surface is broken up by patches or ridges of badly conducting material, the current paths will follow the lines of least resistance, so that it may be difficult to find suitable spots in which to place the earth-pins. It may be stated, as some guide, that under favourable

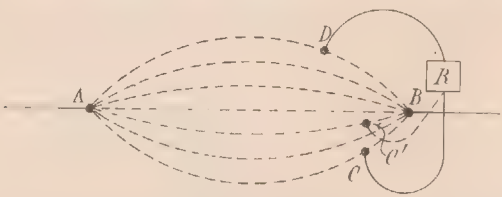

FIG. 135.—Diagram showing Adjustment to Earth-pins.

conditions with regard to earth surface, and using pins 200 yards apart and on a line approximately parallel to the telephone circuit, it is possible, using a valve amplifier, to intercept speech as far as 500 to 600 yards. It is difficult to formulate even approximate rules concerning the "lay-out" of the apparatus for interception of earth currents, so many factors enter into the question, and the values of some of those factors are often entirely unknown. However, two adjustments at least should be made in order to obtain the best results. These are: (1) altering the distance between the earth-pins—*i.e.* placing one, or both, either nearer to or farther from the amplifier, but still in the same straight line; (2) altering the position of one or both, thus forming a line inclined at a greater or less angle from the original trial.

Now, suppose a telegraph or telephone line has a perfect metallic circuit—*i.e.* there are no earth-plates and no leaks to earth. It is clear that interception of messages by the method above described is not likely to be very successful. In this case we must rely upon induction solely. The usual

method is to lay out what is termed a " loop " of insulated wire, the greater part being approximately parallel to the line carrying the signals which it is desired to intercept. This wire must be fairly heavy in section, otherwise its resistance may be such that the weak currents induced in it will be reduced to an unworkable quantity. For the same reason it is not possible to increase the number of turns forming the loop to any great extent, four or five being about the maximum. Using this method it is quite possible to intercept messages from a metallic circuit supported on poles, etc., above ground ; though if twisted wires are employed the

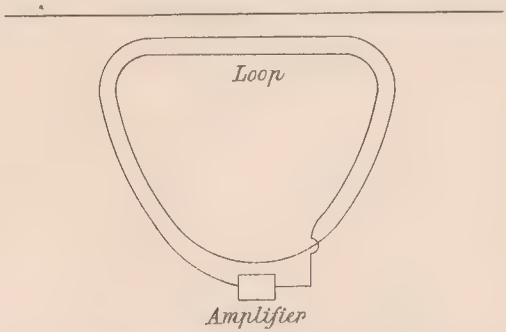

FIG. 136.—Diagram showing Induction " Loop."
(*The full line at top of diagram illustrates the buried cable.*)

method fails. Fig. 136 shows the lay-out for this form of interception. It is hardly likely, however, that the average amateur will experiment much in this direction. It would certainly not be policy to attempt interception from, say, underground telephone cables, and the necessary amount of suitable wire required for the loops would be expensive.

The scheme most suitable would be for two parties to go out to fairly open country and set up a station each. By suitable means signals could be put to earth by one, while the other attempted interception. If both parties were provided with the necessary gear, then once communication was established messages could be exchanged. To put messages to earth deliberately the usual practice is to employ a " power buzzer." This particular buzzer is really a form of induction coil, the primary circuit including the make-and-break device

and the transmitting key, while the secondary is put direct to earth, the terminals being two earth-plates or pins. The French army developed a very fine buzzer, known as the "Parleur," and good signals could, under favourable conditions, be received from it over a distance of 1 to $1\frac{1}{2}$ miles, using a low-frequency three-valve amplifier. The earth base at the buzzer end was somewhere about 100 yards long, while the base at the receiver end would run up to about 200 yards long. It should not be at all a difficult matter for an amateur to construct a buzzer for such a purpose. The iron core of the buzzer should be of well-annealed laminations and shaped so as to form three sides of a rectangle. On one limb the coils are wound, primary next to the iron. The primary should be capable of carrying about 3 amps., and have a total resistance of about 0·27 ohm. The secondary is wound over this (care being taken to provide sufficient insulation) and capable of carrying about 0·5 amp. with resistance of 2·75 ohms. The vibrating armature spans the open side of the rectangular-shaped core so that the whole of the ironwork forms an almost complete magnetic circuit. The armature itself must be pretty heavy and the spring very stiff, so that the vibrations can run up to a frequency of about 800. Contacts must, of course, be ample, anything under $\frac{3}{16}$ in. diam. being useless, as the heating is considerable. A great deal of difficulty was experienced in finding suitable metals for contacts, and the writer believes the best results were obtained using copper and tungsten. Platinum did not behave at all well, a welding of the contacts being quite frequent, while their surfaces soon became pitted and very uneven. Tungsten points are fairly easily obtained, as many ignition spark coils are fitted with them. To prevent undue arcing across the contacts a condenser of about 6 mfds. should be put across them. Fig. 137 will show the connections for the buzzer. A battery of 10 volts capable of discharging at about 4 amps. will provide necessary power. The iron core should be sufficient to allow of the greatest possible magnetic field—somewhere about 0·75 sq. in. in cross section. It will be found that the lower resistance of the earth base the better the note will be, and as far as possible the resistance of the base should not exceed 200 ohms. With such a base, and using 10 volts in the primary circuit, something like 0·2 amp. will be going to earth from the secondary.

Any usual form of low-frequency amplifier will serve for

reception, and with the "Parleur" buzzer a three-valve amplifier was used. A change-over switch enabled transmission or reception to be carried on, using the same earth-plates and pins. Fig. 138 is a diagram of the amplifier used in conjunction with the above-mentioned buzzer, though it was later replaced by a much simpler instrument of quite ordinary type. The diagram is given, as this amplifier presents many features of interest. It is perhaps a little complicated and might well be termed an "all-purposes" instrument. Despite its complexity (and bulkiness) it was, however, a very efficient piece of apparatus. Some readers who saw service in France may recognise it as the famous "I-T." It will be seen that each of the three valves is controlled by a separate switch (fig. 138, S1, S2, S3) and provided with its own filament resistance. The transformer T1 is provided with tappings to its primary winding, while the secondaries of T2 and T3 are also tapped. This is, of course, to give adjustments for best results under various circumstances. The telephones may be plugged into either P1, P2, or P3, according to whether one, two, or three valves are in use. If one valve, then switch S1 is closed, S2 and S3 being open. The 'phones are plugged into P1; and so on. A three-way double-pole switch (EW) is also provided, so that the instrument can be used for earth currents or wireless signals. The switch S4 if open provides for high-frequency work, and if closed for low-frequency. If the instrument is to be used for T.P.S. the line wires are joined to L1 and L2, the three-way switch is put to E, and the primary of the first transformer adjusted till signals are loudest. This adjustment depends largely upon the resistance of the earth conductor. For wireless work, L1 and L2 are joined to an ordinary tuner and the three-way switch put to W. The first transformer is then out of action, the first valve acting

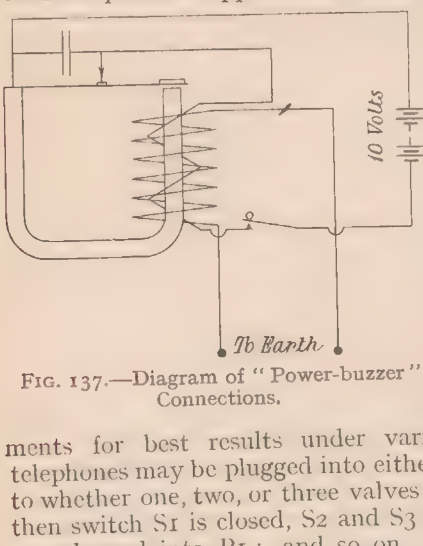

FIG. 137.—Diagram of "Power-buzzer" Connections.

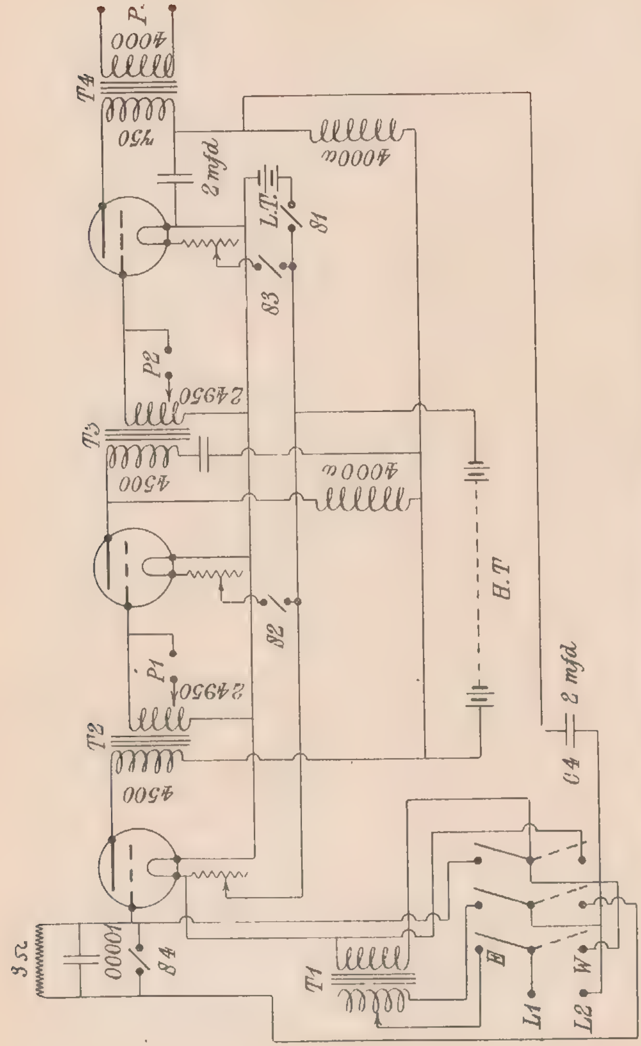

FIG. 138.—Diagram of Amplifier for T.S.F. or Wireless Reception.

as a detector, the second and third acting as amplifiers. Condenser C4 provides a reactance which greatly increases the sensitiveness of the instrument. The figures against the transformers show the number of turns in the windings.

It will occur to most readers, no doubt, that when using a power-buzzer as a transmitter of signals the amplifier will have to be tuned to the same frequency as the break of the buzzer. This is so, and on a busy front where many buzzers were at work jamming frequently occurred, and this was largely obviated by varying the frequency of the buzzer break. This was accomplished by clamping to the free end of the armature small weights of predetermined size, so that the frequency was known. The question of jamming is not likely to prove an obstacle to amateurs practising earth signalling, but is just mentioned in passing.

By suitable means a valve can be made to oscillate at audible frequency and so take the place of a buzzer, though the usual valve is hardly of sufficient size to deal with currents of enough magnitude for serious work. Two or more valves may, however, be used in parallel to overcome this difficulty. Again, where jamming from power-buzzers was very difficult to overcome, it was found possible to use a valve as a generator, letting it work at a frequency above audio and yet below radio frequency. By this means good signals were obtained with a considerable degree of secrecy. The amplifier used to intercept signals of this nature would, of course, be tuned to give beat reception.

In conclusion, then, while earth signalling is not always pure " wireless " practice, there is a good deal connected with the system which comes within the wireless man's scope, and the writer feels sure a good deal of enjoyment and useful work could be obtained from experimenting a little in the matter, and hopes the above notes are of sufficient interest to induce a few enthusiasts to try their hands at what is certainly a little different to the usual " listening-in." There is also this inducement, that now it is so difficult to indulge in a little transmission, the opportunity which earth signalling offers in this direction should make it well worth the while. The writer does not offer a definite ruling on this matter of transmission, but those with whom he has discussed the point seem of the opinion that the restrictions placed on wireless transmission would hardly apply in the case of earth signalling.

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